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EXPERT REPORT OF EDWARD VAUGHN

I. INTRODUCTION

My name is Professor Edward Vaughn. I have been engaged as an expert by BBA Nonwovens Simpsonville, Inc. and BBA U.S. Holdings, Inc. ("BBA") to analyze and provide opinions concerning whether certain claims of U.S. Pat. No. 5,885,909 entitled, "Low or Sub Dernier Fibrous Structures" ("the '909 patent") asserted by E.I. DuPont de Nemours and Co. ("DuPont") in this matter (C.A No. 3-03 0848) are valid. This report contains my conclusions and a summary of my analysis. The report is structured as follows:

- A summary of my conclusions.
- An overview of my qualifications to render an expert opinion.
- A list of resources available to me that help form the basis of my opinions.
- The legal principles applicable to this analysis.
- An overview of the subject covered by the patent.
- My opinion on the validity of the relevant claims.

II. SUMMARY OF CONCLUSIONS

Based on my review of the matters listed below, my understanding of the parties' claim construction positions, and my understanding of the prevailing legal principles, it is my opinion that claims 4, 5, and 64 of the '909 patent are invalid on the basis of anticipation and obviousness, and to the extent that DuPont now contends that the claims of the '909 patent cover SMS fabric the patent is unenforceable for inequitable conduct.

III. QUALIFICATIONS

1. I have more than 40 years of engineering design and research experience in the nonwoven and woven textile field and have published 10 books or monographs, over 25 articles, given over 25 conference presentations at academic and industry conferences, prepared 10 other publications, and given more than 40 other presentations in the woven and nonwoven field.

2. I have managed five major industry-sponsored research projects, and conducted three general surveys of practices and procedures in the textiles industry. Additionally, I have served as a consultant to seven industry projects and five other patent litigations.

3. I have supervised many Masters and Doctor's candidates in their research and preparation of a thesis. I have taught and developed undergraduate and graduate-level courses on the textile industry at Clemson University since 1966.

4. I have organized and conducted the Nonwoven Fabrics Forum from 1970-2002, and in 2004, in addition to giving and organizing dozens of lectures on nonwoven and woven textiles during that time. I have been president, chairman, and board member of various textile professional associations, and edited or prepared numerous publications for textile associations, such as INDA.

5. I have also earned four U.S. Patents on nonwoven processes and materials as part of my research at Clemson University.

6. I earned my B. S. degree in Physics and Mathematics from Lynchburg College (Lynchburg, VA) in 1962; my M.S. degree in Textile Technology from the

Institute of Textile Technology (Charlottesville, VA) in 1964; and my Ph.D. in Fiber Physics from the University of Manchester (Manchester, England) in 1969.

7. Upon graduation from the Institute of Textile Technology, I was employed there as a research associate for two years. I joined the faculty of Clemson University in 1966 as an Instructor in textiles. I took a two-year leave of absence to pursue a Ph.D at the University of Manchester. After receiving my doctorate in 1969 I returned to Clemson University as an Assistant Professor. I was promoted to an Associate Professor in 1973, and full Professor in 1979. During the period from 1977 to 1989 I served as Department Head and then Director of the School of Textiles.

8. In the course of my research, writing, attending conferences, and consulting, I have become familiar with the nonwoven industry.

9. Additional details on my background and experience, including a complete list of my publications, appear in my resume. My C.V. is attached as exhibit A.

10. I have not testified as an expert at trial or by deposition within the last four years.

11. I am being compensated at my standard consulting rate of $175 per hour.

IV. EVIDENCE ANALYZED IN PREPARING THIS REPORT

In forming my opinions for this report, I have considered some or all of the following documents:

- United States Patent No. 5,885,909, its file history, and the references cited in that patent.

- 35 U.S.C. §§ 102, 103 & 112, first paragraph concerning the legal standards for patentability.

- The following additional patents or other prior art literature:

  a. 3,630,816
  b. 3,802,817
  c. 4,041,203
  d. 4,374,888
  e. 4,442,161
  f. 4,499,139
  g. 4,622,259
  h. 4,630,603
  i. 4,671,266
  j. 4,681,798
  k. 4,808,467
  l. 4,908,163
  m. EPO 0 365 293
  n. 4,988,560
  o. 5,035,943
  p. 5,141,699
  q. 5,204,165
  r. 5,288,536
  s. 5,308,691
  t. 5,368,920
  u. EPO 0 674 035
  v. 5,484,645
  w. 5,492,751
  x. 5,492,753
  y. 5,498,463
  z. 5,549,964
  aa. 5,545,371
  bb. 5,597,647
  cc. 5,582,903
  dd. 5,605,739
  ee. 5,652,048
  ff. 5,667,749
  gg. 5,688,468
  hh. 5,771,970
  ii. 5,807,795
  jj. 5,811,178
  kk. 5,928,209
  ll. 5,939,341
  mm. 5,952,252
  nn. 6,114,596
  oo. WO 97/35053;

- BBA's Preliminary Invalidity Contentions (and the documents cited therein);
- DuPont production bates nos. DNW0161318-DNW0161320; DNW162239-DWN162240;
- BBA production bates nos. BBA 000427-492, 000493-498, 000499-508, 000563-84, 000607-8, 000611, 000613, 000664, 000673-78, 000683-90, 00048-55, 000784-92, 001363-69, 001478, 001480, 001482-83, 001502-08, 001658-68;
- Vasathakumar Narayanan, et al., *Nonwovens Technology Primer*, Nonwovens Industry (1994) (attached as Exhibit B).

V. MY UNDERSTANDING OF THE APPLICABLE LEGAL PRINCIPLES

I. *Legal Standards and Factors to be Considered – Invalidity under §§ 102, 103*

I have been informed that after claim terms have been construed, one may then assess validity by comparing a patent claim to the "prior art." A prior art "reference" is considered prior art for all that it discloses or teaches to one of ordinary skill. A reference will be prior art if it satisfies the rules set out in 35 U.S.C. § 102, including, for example, the requirement that the reference have an effective date (e.g., publication date) either more than one year before the patent was filed, or before the patent's date of invention. A patent claim is not valid if the claimed invention was known or used by others in the United States or was patented or was described in a printed publication in the United States or a foreign country before the invention thereof by the patentee. Also, a patent claim is not valid if the

claimed invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the patentee.

It is my understanding that if a single prior art reference discloses or teaches to one of ordinary skill every element of a patent claim, that claim is said to be "anticipated" and is invalid. A prior art reference may teach or disclose a claim element either expressly or inherently. A reference inherently discloses an element if one of ordinary skill must recognize from what is expressly disclosed that the element is necessarily present in the method or device that is the subject of the reference.

Obviousness

Even if not anticipated by a single reference, a patent claim may still be invalid if it is obvious in view of one or more prior art references. I understand that to be proven invalid as "obvious," the invention must have been obvious to a person of ordinary skill in the art at the time the invention was made. I understand that, to determine whether a claim is obvious, a person must (1) determine the scope and content of the prior art; (2) identify the differences between the asserted claims and the prior art; (3) determine the level of ordinary skill in the pertinent art at the time the invention was made; then (4) decide whether each claim as a whole would have been obvious to a person of ordinary skill in the pertinent art when viewing the prior art.

I also understand that a patent may be obvious in light of more than one prior art reference, but that there must be a motivation or suggestion to combine the references. The suggestion or motivation to combine may come from the references themselves, the knowledge of one skilled in the art that certain references are of

special interest in a field or from the nature of the problem to be solved. I have also been advised that it is improper to use hindsight in making the obviousness determination by using the patent as a guide through the prior art references, combining the right references in the right way so as to achieve the result of the patent claims. The motivation, however, need not appear in any written document, so long as it is not based on hindsight.

In order to assess the "scope and content of the prior art," as noted above one must first determine what references qualify as "prior art." Once the scope of the art is determined, one must then assess what each reference teaches and whether there is a motivation to combine its teachings with other references.

Once one understands the teaching of the prior art, one must determine the differences between that teaching and what is claimed in the patent. Again, there must be a motivation or suggestion in the prior art to combine the references to overcome the differences each reference has from the claimed invention.

To assess the level of ordinary skill in the art, I understand one can consider the types of problems encountered in the art, the prior solutions to those problems found in prior art references, the speed with which innovations are made, the sophistication of the technology and the level of education of active workers in the field.

I understand that before a final determination of obviousness is made, one may consider any evidence that exists as to so called "secondary considerations" tending to establish non-obviousness, including for example: commercial success of the patented invention, long-felt need, failure of others, teaching away, and copying and praise by others in the industry.

II. ***The Written Description Requirement of § 112 and Enablement***

I understand that a patent claim is also invalid if the claimed subject matter is not sufficiently described or enabled by the patent's specification. According to 35 U.S.C. § 112:

> The specification shall contain a written description of the invention, and the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same.

I am informed that for the patent to have a sufficient written description, "what is claimed by the patent application must be the same as what is disclosed in the specification." The specification need not describe the claimed subject matter using exactly the same terms as the claim, but must "indicate to persons skilled in the art" that, as of the date the patent application was filed, "the applicant had invented what is now claimed." The test for determining compliance can be stated as whether the disclosure of the application as originally filed reasonably conveys to those skilled in the art that the applicant had invented the subject matter as defined in the claims of the patent.

The purpose of this requirement is to ensure that the public, in exchange for the patent rights given to the inventor, obtains from the inventor a full disclosure of how to carry out the invention. If the inventors failed to provide an enabling disclosure, the patent is invalid. However, because descriptions in patents are addressed to those skilled in the art to which the invention pertains, an applicant for a patent need not expressly set forth in his specification subject matter which is commonly understood by persons skilled in the art.

The enablement defense does not require an intent to withhold; all that is required is a failure to teach how to practice the process. In other words, if a person of ordinary skill in the art could not carry out the process without undue experimentation, the patent is invalid. A specification need not contain a working example if the invention is otherwise disclosed in such a manner that one skilled in the art to which the invention pertains will be able to practice it without an undue amount of experimentation.

III. *Presumption of Validity*

It is my understanding that once issued by the USPTO, a patent is presumed to be valid. In order to prove a patent invalid, the challenger must present what is referred to as "clear and convincing" evidence of invalidity.

IV. *Level of Ordinary Skill in the Art*

The field of the invention is the production and properties of nonwoven fabrics. One skilled in the art would have knowledge of the various methods of making nonwoven materials and the uses to which nonwovens are put. Additionally, to be effective, one skilled in the art would have the necessary engineering skills or experience to make nonwoven fabrics. One skilled in the field would be able to use a variety of processes, concepts and disparate elements and combine these to achieve a desired result. To this end, one skilled in the art would have an interest in developments and advances in allied fields, such as woven textiles, environmental factors affecting performance of the fabrics, and advances and concerns in the market segments in which the products of interest are used.

VI. THE PRINCIPLES OF NONWOVENS

Since the 1970's, thousands of patents on nonwoven materials have been issued. Much of these efforts were directed to developing fabrics which had an optimal combination of physical and aesthetic properties. Some of the elements which are important for a nonwoven material include:

Tensile Strength	Absorbency	Shiny/Dull
Elongation	Fluid Retention	Fuzzy/Flat
Burst Strength	Wrinkle Resistance	Smooth/Rough
Tear Strength	Weight/Mass	Pliable/Crunchy
Toughness	UV Resistance	
Impact Resistance	Flammability	Surface Texture
Tear Propagation	Chemical Resistance	Warm/Cold
Seam Strength	Static Generation	Comfortable
Abrasion Resistance	Dyeability	Stretchy
Compression Resistance	Biodegradability	Fluffy/Hard
Elasticity/Brittle	Dye Stability	Bright/Dull
Surface Friction	Melting Behavior	Reversible
Moisture Vapor and Air	Cleanability	Price
Permeability	Color	Cost Effectiveness
Fluid Porosity	Toxicity	Safety
Water Repellency	Printable	Disposable/Durable
Thickness	Soft/Stiffness	Environmental
Density/Bulk	Opaque/Transparent	
Thermal Conductivity	Fragrance/Odor	

Many of these elements differ in importance for the application. Some filter applications may favor strength, filtering capacity, and air permeability more than drapability and feel; alternatively, some medical applications place a high premium on fluid resistance in order to protect the wearer. Almost all applications value strength highly. Many of these elements can be increased only at the expense of another. Therefore, a combination of properties appropriate for one situation may not be appropriate for another, and so manufacturers of nonwoven fabrics must always balance the above elements to create an optimum configuration of properties for the use.

A few of the methods and techniques used to achieve different combinations of properties in nonwovens that were known at the time the '909 patent was filed include: stichbonding; needlepunching; hydroentanging; parallel fibers; randomized batts; crosslapped layers; isotropic fiber layers; gravimetric feeding; wet-laid slurry; spunbond; meltblown; film; mechanical opening; volumetric blending; controlled fiber layers; sprayed latex or powder, saturated, printed or frothed latex; use of solvents; heat, heat stretch, perforation; thermal calendering; use of a radiant or convection oven; use of a vacuum drum or mold; laminating; sonic welding; other slitting or winding. This is only a very small sampling of some of the older methods for nonwoven manufacturing, and does not include many of the methods explained in the prior art below.

VII. THE '909 PATENT

The '909 patent relates generally to a sheet of nonwoven material which has a high hydrostatic head and high air permeability. The patent states that the combinations of hydrostatic head and air permeability would be useful in many fields. Specifically, the patent states that the invention could be useful for protective medical apparel and filters, as well as in wipes or other absorbent applications. (Col. 6, lines 12-13; col. 9, lines 17-21; col. 9, line 67-col. 10, line 3). These applications could benefit from new materials with higher hydrostatic head and/or air permeability.

The '909 patent appears to describe a single-layer sheet (col. 2, lines 7-40). The patent is directed at improving over prior art which used meltblown fibers which were not strong enough to be used without a supporting scrim. (Col. 1, lines 60-64). The purported improvement of the '909 patent over the prior art is

improved liquid barrier and air permeability. (Col. 1, line 65 to col. 2, line 4). The '909 patent mentions that the improvement is due to the use of specific steps, and in particular to the use of a particular type of fiber. (Col. 4, lines 8-13). The patent states that: "it has been found that when hard yarn meltspun microfibers are used to create a nonwoven fibrous structure, the resulting fabrics have extraordinarily high Frazier permeability. This is new." (Col. 3, lines 60-64). The patent states that these fibers also give the material the strength it needs without a supporting scrim. (Col. 3, line 65 to col. 4, line 1; col. 5, lines 57-64). The patent attributes the improved properties and strength of the fabric to the use of hard yarn subdenier fibers. (Col. 3, lines 60-64). The patent does not appear to be directed to SMS fabric, in which one or more layers of fragile meltblown are supported between two stronger layers of spunbond, but rather to a new, stronger single sheet which does not require a scrim for support.

The patent describes two examples of how to achieve the stated values, a wet-lay process and a hand-made method. The wet-lay process is described in some detail below during the § 112 discussion. Although this wet-lay process does produce strong hydrohead and air permeability values, these fabrics likely have poor performance in other areas. Attempting to raise these other values might result in the lowering of the air permeability and hydrostatic head values.
The other method is described as a hand-made method, although exactly how that is done is not clear from the text. There are many different ways of making a fabric by hand using pre-made fibers. It is not clear what tradeoffs in other factors are implicit in the use of the hand-made process referenced in the '909 patent.

I am informed that the only claim asserted in the present litigation is claim 64, as it reads on claims 4 and 5. The claims are reproduced below as follows:

> 4. A flexible sheet material having a Frazier permeability of at least about 15 m^3/min-m^2 and an unsupported hydrostatic head of at least about 40 cm.
>
> 5. A flexible sheet material having a combination of Frazier permeability and hydrostatic head properties selected from the group of:
>
> a Frazier permeability of at least 70 m/m[1] and an unsupported hydrostatic head of at least about 15 cm.;
>
> a Frazier permeability of at least 28 m/m and an unsupported hydrostatic head of at least about 30 cm.;
>
> a Frazier permeability of at least 15 m/m and an unsupported hydrostatic head of at least about 40 cm.; and
>
> a Frazier permeability of at least 1 m/m and an unsupported hydrostatic head of at least about 80 cm.;
>
> 64. The sheet material according to any of claims 1, 3, 4, 5, 6, and 7 wherein the material has a cross sectional void percentage of at least about 85 percent.

I understand that DuPont is only asserting claim 64 in combination with claim 4, and with the fourth subpart of claim 5. I will therefore limit my analysis where possible to claim 64 as it reads on claim 4 and the fourth subpart of claim 5.

VIII. CLAIM CONSTRUCTION

I understand that in analyzing whether a claim is valid, one must consider how the language has been interpreted or "construed" by the Court. The claims, as construed, are then compared to the prior art. I have been informed that the Court has not yet issued a claim construction ruling.

I am informed that the parties dispute the meaning of some of the terms in claims 4, 5, and 64 of the patent. In particular, I am informed that the following

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[1] To simplify the text of this report, I will abbreviate m^3/m^2-min as m/m.

relevant terms remain subject to claim construction: "sheet material," "at least about," and "cross sectional void percentage."[2] While I do not agree with DuPont's arguments with respect to the proper construction of these terms, I will assume DuPont's proposed construction is correct for many of these terms for purposes of this report. This is necessary because if the claims are construed following BBA's contention that the claims exclude SMS materials, there is no infringement, and the validity question would then be moot.[3] For example, while I do not agree that the '909 patent includes more than a single sheet and/or that it is includes SMS fabric, I have assumed for purposes of my invalidity analysis that it does.

I also disagree with DuPont's proposed construction of the term "cross sectional void percentage." The term has no meaning in the field of nonwovens and there is no test method for determining it. The '909 patent also provides no guidance as to how to test for it. However, again, for purposes of my invalidity analysis, I am applying DuPont's view of what the term means. DuPont has not provided a proposed construction of the term "cross sectional void percentage" that would allow one of skill in the nonwovens art to measure it, but apparently argues

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[2] I am informed that claim 69 was previously asserted by DuPont but is not longer asserted, and thus the construction of any terms in this claim are no longer relevant to the case.

[3] I reserve the right to supplement this report on the topic of inequitable conduct. In an email string from Mar. 10-12, 1996, which involved at least three of the inventors, Rudolph Janis, Hyunkook Shin, and Edgar Rudisill, the properties of a Kimberly-Clark SMS fabric were discussed and circulated. (DNW0161318-320). The fabric in question had measured hydrohead values of 68.5, 71, and 70 cm and measured air permeability values of 14.1, 12.0, and 11.4 m/m. This fabric would be covered by some of the claims of the patent (such as 4, 5, 10 and 11) if those claims were construed to include SMS. However, no Kimberly-Clark SMS fabric was disclosed to the PTO. I understand that BBA is moving to amend its pleadings to allow for the inequitable conduct claim. Should BBA be successful in amending the pleadings, I will supplement this report with my opinion on inequitable conduct.

that it is a calculation that can be performed based on other measurements and data, such as the thickness of the fabric and the density of the material.[4] I am told that one of the inventors of the '909 patent, Hyunkook Shin, described the measurement of "cross sectional void percentage" as a measurement of void using the following formula. Take the basis weight of the fabric and divide it by the thickness of the fabric. This results in the density of the fabric. Then, figure out the density of the fiber, which can be obtained from reference books. Then, compute the "cross sectional void percentage" using the following formula: ((Fiber density - Fabric density) / Fiber density) * 100.[5]

Because measurements necessary to calculate the "cross-sectional void percentage" under DuPont's understanding are unavailable for most of the prior art, I will calculate void percentage where data are available based on DuPont's apparent understanding, using the formula provided by Dr. Shin. Otherwise I will determine as best I can, given the informational constraints, whether it would be obvious to one of skill in the art to engineer a fabric to have a void percentage of "at least about" 85%.

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[4] I reserve the right to supplement this report should DuPont articulate a different method of calculating cross sectional void percentage than I have assumed for the purposes of this report.

[5] While I am applying this computation for purposes of this report, I believe that if the term "cross sectional void percentage" had any meaning, it would not be measured in this manner. One problem with such a calculation is that it does not account for any bond points that may exist in the fabric, or for chemical additives, which would necessarily change the void volume. "Cross sectional void percentage," if it means anything, would be a measurement of the volume of voids in a cross section of material divided by the total volume of the cross section of the material and multiplied by 100. DuPont and Dr. Shin's calculation does not measure a cross section of the material. Dr. Shin merely describes a standard porosity calculation. This calculation makes somewhat more sense for the fabric described in the invention, because it is basically fibers glued together with an acrylic binder—it has no bond points to worry about. Transferring this calculation to fabrics with a significant number of bond points is clearly problematic.

Lastly, due to the complexities inherent in comparing measurements made by different test methods under different conditions in different labs, I will not attempt to assess what such measurement would be if conducted under DuPont's chosen tests. There will be some variability of the results in the prior art depending on the test method and procedure, and my analysis will recognizes that there may be some variability in test results.

VIII. INVALIDITY UNDER 35 U.S.C. §§ 102, 103.

Applying the above criteria, I conclude that claims 4, 5, and 64 are invalid as they are anticipated and/or obvious as discussed below, and that the patent is also invalid for lack of an adequate written description.

A. EFFECTIVE FILING DATE

The '909 patent claims the benefit under 35 U.S.C. § 119(e) of United States Provisional Application No. 60/019,277 which was filed June 7, 1996. I am informed that under 35 U.S.C. § 111(b) a provisional application can be filed by an applicant in order to establish a priority date for the subject matter described in the provisional application. Under §119(e)(1), the applicant can be entitled to the benefit of the earlier filing date of the provisional application. However, § 119(e)(1) requires that the earlier provisional application must have disclosed the invention in the manner provided by the first paragraph of § 112.

§ 112 contains the requirement that a specification "shall contain a written description of the invention." Although the applicant does not have to describe exactly the subject matter claimed, the description must convey to those skilled in the art that the applicant had invented the subject matter defined in the claims.

It is apparent that the '909 patent applicant has added substantially to the text of the provisional application, and that the provisional application does not contain a written description of claim 5 of the invention as defined by the claims of the '909 patent. Specifically, the provisional application states that "[a]fter calendering, the hydrostatic head may be brought up to as much as 45 to 50 cm while the Frazier remains in excess of 25 m/m." These are the highest values of hydrohead mentioned in the written description, aside from the numbers in the examples, which are not explained.

Until the '909 utility application was filed, there was no mention of the 1/80 air permeability/hydrostatic head combination. The test of the '909 application provides *for the first time* a characterization of the invention as covering a combination as high as 1 m/m and 80 cm. From the description given in the provisional application a person of skill in the art would not arrive at the combination of 1 m/m Frazier permeability and 80 cm hydrostatic head in claim 5 of the '909 patent, nor would person of skill in the art recognize these values as being something that defined the inventors' invention. Certainly there is no indication at all that the patent would cover the combination of 1 m/m Frazier permeability, 80 cm hydrostatic head, and 85% cross-sectional void percentage. Therefore, the effective filing date for claim 5, and for claim 64 insofar as it depends on claim 5, is the June 9, 1997 filing date of the '909 application, not the filing date of the provisional application.

It should be noted, however, that the following analysis does not depend on an effective filing date of June 9, 1997 to find claim 64 invalid.

B. ANTICIPATION & OBVIOUSNESS

As an initial matter, I should note that "cross sectional void," or porosity, as DuPont appears to define this term, is not a standard measure of nonwoven materials. By itself, the measurement does not mean very much, except insofar as it may relate to other measurable factors such as filtering capacity or air permeability. However, if a person desired to know the filtering capacity or air permeability, he or she would do better to simply measure those values using a standard test. It is simply not a very useful measurement.

Another limitation of void percentage, as calculated by DuPont, should be noted as it relates to obviousness. Because void percentage is directly affected by the thickness of the material, the void percentage can be easily changed. For example, a sheet of pure plastic, with a void percentage of 0, could be changed to have a very high void percentage simply by adding a piece of felt (another type of nonwoven with a very high "void percentage") on top. Even with a high void percentage, the fabric would still have an air permeability of 0. For example, DuPont's Tyvek, which typically has a fairly low void percentage, often below 70%, could easily be made to have the claimed properties by laying some spunbond layers on top. The spunbond would do little or nothing to change the air permeability and hydrostatic head of the Tyvek, but by changing the thickness, it would increase the void percentage to almost any value.

Nonwoven fabrics typically have a void percentage between 55-93%. Vasathakumar Narayanan, et al., *Nonwovens Technology Primer*, Nonwovens Industry, at Table 3 (1994). The limitation in claim 64 adds nothing that would not be inherent in nonwovens anyway.

The examples of the '909 patent demonstrate a correlation between air permeability and void percentage. From these examples, it appears that a fabric with an air permeability of around 15 m/m will have a void percentage of around 85%.[6] Supporting this, much of the prior art discusses porosity of a fabric synonymously with air permeability. For example, the '647 patent uses the term "Frazier porosity" to mean air permeability. ('647 patent, col. 9, line 26). Because it is clear that the amount of void in a material can be correlated with its air permeability, it is obvious that one of skill in the art would be able to modify a particular fabric to obtain a void percentage of "at least about 85%," as required by claim 64, just as air permeability can be and is modified.

Finally, all of the patents below explicitly teach various techniques for increasing both the hydrostatic head and the air permeability.[7] Because these particular properties are sought after in many applications, a person of skill in the art would have the motivation to combine these techniques to produce a fabric with the claimed properties. Many other techniques not listed below would also be known to a person skilled in the art and applied to the problem of attaining the

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[6] This observation is supported by those examples in the prior art where a calculated void percentage was possible. See the discussion of U.S. Pat. Nos. 4,622,259, 5,492,753 & 6,114,596, infra. From these patents, and the '909 patent, it seems clear that a fabric with an air permeability of around 15 m/m will have a void percentage of around 85%.

[7] It should be noted that claim 5 uses the term "unsupported hydrostatic head." The parties agree that unsupported means that the hydrohead test was performed without a supporting scrim. Only materials which are too weak to withstand the hydrostatic head test use a scrim. Fabrics such as SMS do not need a supporting scrim, and nearly all of the examples in the patents which follow are SMS. In any case, hydrostatic head testing is usually done without a scrim, and if the testing reported in a patent had been done with a scrim, it would likely have been reported as such. Even the hydrostatic head tests reported in the '909 patent do not specify whether they were supported or unsupported. Therefore, for the purposes of this report I will assume that hydrostatic head tests are unsupported unless otherwise indicated.

desired properties. It is the nature of the nonwoven field that a person of skill in the art would consult the literature, using many different methods and techniques, like those described above, to achieve desired characteristics. Finally, it should be noted that all of the below prior art directly concerns the discrete field of nonwovens.

I incorporate the above commentary for each reference that follows.

a. U.S. Pat. No. 4,374,888

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example 1	58	7.9	Obvious
Example 2	55	8.5	Obvious

(col. 7, tables I & II);

This patent teaches that one can control the physical properties of a nonwoven fabric by varying the ratio of spunbond and meltblown in a composite structure. It shows that one can attain selected levels of permeability and repellency by varying the ratios. This teaching allows a person to engineer a composite nonwoven structure for a variety of specific applications. In examples 1 and 2, the properties of a particular fabric changed from a hydrostatic head of 58 cm and air permeability of 7.9 m/m to 55 cm and 8.5 m/m, respectively.

Using this teaching, the others set out in the following patents and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claim 4 of the '909 patent.

b. U.S. Pat. No. 4,622,259 ('259 patent)

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example 1	49	18	85.7
Example 3	42	11	83
Example 7	75	1	73.3

(col. 15, lines 11-27);

The '259 patent uses long meltblown fibers which are 10-20 cm in length, which is very unusual for a meltblown, and fibers that average 7 microns in diameter, which is very small.

This patent clearly anticipates claim 64 as it depends on claim 4 because it meets each of the limitations of the claim. Also, based on the method of bonding, a method of controlled aperturing, or other methods disclosed in the prior art, it would be relatively simple for a person skilled in the art to engineer a fabric of the types disclosed in the patent to yield a hydrohead of 80 cm and an air permeability value of 1 m/m and a void volume of 85%.

Using these teachings and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

c. U.S. Pat. No. 4,908,163

This patent teaches uses of coated fabric technology to attain desired properties. It has the same examples as the '259 patent, and so the same arguments apply as to anticipation and obviousness with respect to claim 64.

d. U.S. Pat. No. 5,204,165

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example 1	35.6	18.3	Inherent/Obvious
Example 2	48.3	14	Inherent/Obvious

(col. 5, lines 34-36, lines 49-51; col. 6, lines 13-15; col. 6, lines 65-68; col. 7, lines 15-16);

This patent teaches sandwiching pulp between two layers of spunbond and thermal and ultrasonic bonding, and teaches that by varying the amount of pulp, one can change the air permeability and hydrostatic head. The difference between example 1 and example 2 is the amount of eucalyptus fiber sandwiched inside the spunbond. Based on the preceding discussion and the air permeability values given in the example, and because the use of pulp will likely give this patent an increased void percentage, the void percentage of these examples is more than likely above 85%.

This patent therefore anticipates claim 64 by inherency as it depends on claim 4 because it inherently meets all of the limitations of that claim, especially if "at least about" is construed as including values of +/- 1 m/m.

Alternatively, using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters of the examples to attain the combination of properties in claim 64 as it depends on claim 4 of the '909 patent.

e. **U.S. Pat. No. 5,308,691**

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example 1 (#2)	86	2	Obvious
Example 3 (table 4)	124	1.5	Obvious

(col. 4, lines 50-53; col. 6, table 1; col. 7, table 4; col. 8, tables 5-7; col. 9, lines 1-29);

This patent teaches the use of fibers with a denier less than 5. This patent takes polyproplyene Typar and adds some meltblown fibers to show they get a

"dramatically improved" air permeability. This patent teaches that one can change the hydrostatic head and air permeability of an SMS fabric by changing the bonding conditions, namely the composition of the unheated non-metal roll. The patentee laminated the examples using a hard metal roll and a soft cotton filled role—which shows that one can simply vary the surface of the cotton filled roll and the void percentage will change. Additionally, because the weight and the thickness may be altered, one can alter the void percentages.

The examples cited above are suited for use as housewrap products. Housewrap products require good barrier properties and good insulation characteristics. To attain good thermal insulation one increases the void volume to trap air. One of skill in the art could control hydrostatic head by the small diameter fibers of the meltblown. While keeping the hydrostatic head, it would be possible to increase the void volume by altering the thickness, and one can alter the thickness by the method of bonding. Because these are SMS housewrap products which likely use a fairly large void volume, the example fabrics could be engineered to have a void percentage in excess of 85%, if they do not have this inherently.

The above examples anticipate claim 5. Moreover, the above examples anticipate claim 64 as it depends on claim 5 because a void percentage of over 85% is probably an inherent characteristic of the fabrics.

Alternatively, using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters of

the examples to attain the combination of properties in claim 64 as it depends on claim 5 of the '909 patent.

f. European Patent 0 674 035 ('035 patent)

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example 1	35.6	18.3	Inherent/Obvious
Example 2	37	48.8	Inherent/Obvious
Example 3	48	32	Inherent/Obvious
Example 4	58	15.2	Inherent/Obvious
Example 5	65	13.7	Inherent/Obvious
Example 6	46	11.6	Obvious

(p. 2, lines 29-35; p. 6, lines 43-45; p. 8, table 1; p. 8-9, claims);

This patent teaches that a nonwoven fabric can be engineered using combinations of well-known techniques and materials to yield desired levels of hydrohead and air permeability. Based on the preceding discussion and the air permeability values given in the example, the void percentage of examples 1-5 will inherently be above 85%.

Because it meets all of the limitations of claim 4, this patent anticipates claim 4. Further, this patent clearly anticipates claim 64 as it depends on claim 4, because it meets all of the limitations of claim 64 either explicitly or inherently.

Using this teaching, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

g. U.S. Pat. No. 5,484,645

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example x (Table 2)	38.9	25.3	Inherent/Obvious

Example 2 (Table 2)	37.8	23.7	Inherent/Obvious

(claims 2-3, 13-15 and 17; cols. 8 & 9, table 1; col. 9, lines 37-40; col. 9, lines 1-29);

Based on the preceding discussion and the very high air permeability values given in the example, the void percentage of the above examples will inherently be above 85%.

If "at least about" is interpreted to include values of +/- 1.1, this patent invalidates claim 4 as anticipated. This patent invalidates claim 64, as it depends on claim 4, as anticipated by inherency.

Alternatively, using the teaching of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 of the '909 patent.

h. U.S. Pat. No. 5,492,751

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Example 1	45	22.9	Inherent/Obvious

(col. 7, table 1; claims 1, 10-12);

This patent teaches the production of a low basis weight barrier fabric. From a commercial standpoint, this fabric weight range would be desirable as a product made therefrom would be lighter and hence more cost effective. It would also allow for more variation in the parameters, specifically adding more fibers to increase the hydrostatic head. Based on the preceding discussion and the air

permeability values given in the example, the void percentage of examples 1-5 will be above 85%.

This patent anticipates claim 64 as it depends on claim 4, because they meet all of the limitations of claim 64 either explicitly or inherently. This patent also invalidates claim 4 as anticipated.

Using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

i. U.S. Pat. No. 5,492,753 ('753 patent)

	Hydrostatic head (cm)	Air permeability (m/m)	Void (%)
Control (Example 2)	67	9.5	87
Inventive fabric (Example 2)	72	9.8	88

(col. 4, lines 50-52; col. 6, lines 42-57; col. 7, lines 1-9; col. 11, lines 32-34; col. 11, lines 58-63; col. 20, table 6; claims 14-16);

This patent teaches the mechanical stretching of a nonwoven laminate component as a means of enhancing barrier properties, namely the hydrostatic head and Frazier porosity.

If the '909 patent is found enabled, this patent has the air permeability and void percentage required by claim 64. The examples in this patent have numbers very similar to the example fabrics in the '909 patent. The fabric shown in examples 20-25 has a hydrohead which is higher by 2 cm, but a lower air

permeability and a much lower void percentage. (See the discussion on invalidity under § 112). Although the examples in this patent do not anticipate claim 64 as it depends on claim 5, it comes closer to claim 64 *than do any of the actual examples in the patent*. Therefore, if this patent is not found to anticipate claim 64, or render it obvious, then the '909 cannot be found enabled.

Using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

j. U.S. Pat. No. 5,498,463

This patent is the US equivalent of the '035 EPO patent described above. As the 035 patent invalidates claims 4, 5 and 64 for obviousness and anticipation, so this patent also invalidates those claims.

k. U.S. Pat. No. 5,597,647

	Hydrohead (cm)	Air permeability (m/m)	Void (%)
Table 1 (Evolution 3)	53	12.2	Obvious
Table 1 (Example)	77	12.6	Obvious

(col. 9, table 1)

The '647 patent teaches that the treatment of a nonwoven laminate component with a surface active agent, such as a fluorocarbon, can alter the physical properties of the nonwoven structure, such as hydrostatic head. In the examples, the hydrohead increased from 53 to 77 cm and the air permeability increased from 12.2 to 12.6 m/m. One can learn from other prior art that changes in

the physical geometry of the fibers changes the fabric properties. The '647 patent reinforces this knowledge base to include the use of chemical treatments to engineer specific fabric properties. Based on the preceding discussion and the air permeability values given in the example, the void percentage of the above examples is likely above 85%.

If "at least about" is interpreted to include values of +/- 2.8, this patent invalidates claim 64 as it depends on claim 4 and 5 of the '909 patent as anticipated by inherency.

Using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

l. U.S. Pat. No. 5,582,903

This patent has the same relevant data and examples as the '753 patent, and therefore anticipates and renders obvious claim 64 of the '909 patent.

m. U.S. Pat. No. 5,652,048 ('048 patent)

	Hydrohead (cm)	Air permeability (m/m)	Void (%)
Example 3 (before)	90.8	9.6	Obvious
(after)	121.6	6.8	Obvious

(col. 15, Table 3-2);

This patent teaches the modification of a manufacturing parameter, specifically the perturbation frequency, to change the hydrohead and air permeability of a fabric. Based on the preceding discussion and the air permeability

values given in the example, the void percentage of the above examples may be above 85%, and could certainly be engineered to be above 85%.

Because it meets all of the limitations of claim 5, this patent anticipates claim 5.

Based on these examples and teachings, it would be obvious to one of skill in the art how to make a fabric in which the hydrostatic head and other properties can be increased to include those values claimed in claims 4 and 5 of the '909 patent.

n. U.S. Pat. No. 5,667,749

This patent has the same relevant data and examples as the '970 patent, below. Therefore, this patent invalidates claims 4, 5, and 64 of the '909 patent by anticipation by inherency and obviousness.

o. U.S. Pat. No. 5,771,970 ('970 patent)

	Hydrohead (cm)	Air permeability (m/m)	Void (%)
Example 1 (before)	86.4	13.8	Inherent/Obvious
(after)	103	10.9	Obvious
Example 3 (before)	90.8	9.6	Obvious
(after)	121.6	6.8	Obvious

(col. 12, Table 1-1; col. 15, table 3-2)

This patent teaches the modification of a manufacturing parameter, specifically the perturbation frequency, to engineer fabric properties, specifically Frazier porosity and hydrostatic head. As the examples above show, the hydrostatic head was substantially higher after the treatment, while the air permeability decreased somewhat. Based on the preceding discussion and the air permeability

values given in the example, the void percentage of the above examples, especially the "before" examples, can be said to be around 85%.

Because it meets all of the limitations of claim 5, this patent anticipates claim 5. This patent invalidates claim 64 as it depends on claim 5 of the '909 patent as anticipated by inherency. Further, if "at least about" is construed to mean +/- 1.2, this claim anticipates by inherency claim 64 as it depends on claims 4 and 5.

Using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

p. U.S. Pat. No. 5,807,795

This patent has the same relevant data and examples as the '970 patent. Therefore, this patent also anticipates and makes obvious to one skilled in the art in the same way as the '970 patent the properties described in claims 4, 5 and 64 of the '909 patent.

q. U.S. Pat. No. 5,811,178

This patent has the same relevant data and examples as the '048 patent. Therefore, this patent also anticipates and makes obvious to one skilled in the art the same was as the '048 patent the properties described by claims 4, 5, and 64 of the '909 patent.

r. U.S. Pat. No. 5,939,341

	Hydrohead (cm)	Air permeability (m/m)	Void (%)
Example 1	85	7.6	Obvious
Example 4	100	<1	Obvious
Example 6	70	6.4	Obvious

(cols. 7-10, table I).

Based on the preceding discussion and the air permeability values given in the example, the void percentage of the above examples, it would be obvious to one skilled in the art to adjust the examples here to have a void percentage of 85%.

Because it meets all of the limitations of claim 5, this patent anticipates claim 5.

Using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

s. **U.S. Pat. No. 5,952,252**

	Hydrohead (cm)	Air permeability (m/m)	Void (%)
Kimberly-Clark Ultra	80.6	6.7	Obvious

(col. 12, line 66-col. 13, line 5; col. 13, table 1).

Based on the preceding discussion and the air permeability values given in the example, the void percentage of the above examples, it would be obvious to one skilled in the art to adjust the examples here to have a void percentage of 85%.

Because it meets all of the limitations of claim 5, this patent anticipates claim 5.

Using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the

combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

t. U.S. Pat. No. 6,114,596

	Hydrohead (cm)	Air permeability (m/m)	Void (%)
Example #20	39.8	29.5	98%

(cols. 11 & 12, Table I);

Because it meets all of the limitations of claims 4 and 64, this patent anticipates claims 4 and 64.

Alternatively, using the teachings of this patent, the others set out in the preceding and following patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

u. Documents from BBA and DuPont's production

Where given, the figure is an average of data or individual results. Where data has not been averaged, I have indicated a range of the numbers included in the document. Averaged data is indicated with *. Expected averages from product specifications are indicated with **.

BBA doc. number	Name of fabric	Hydrohead (cm)	Air permeability (m/m)	Void percentage	Date
433	Sterisure	52-54	18.3	Inherent/ Obvious	Sept., 1994
439	Sterisure	47-52	15-20	Inherent/ Obvious	Sept., 1994
	Spunguard	43-50	15-17	Inherent/ Obvious	Sept., 1994
441	Sterisure 1.4 osy	58-61	20-22	Inherent/ Obvious	Sept., 1994

443	Sterisure 1.8 osy	52-53	19-20	Inherent/ Obvious	Sept., 1994
496	Suprashield	53-58	14-17	Inherent/ Obvious	Sept., 1994
499-508	Securon	45	18.3	Inherent/ Obvious	1995
583-84	HAWK	65.59*	18.1*	Inherent/ Obvious	Sept. 1995
574-75	R1011	52.1*	23.8*	Inherent/ Obvious	Oct. 1995
564	T0431	43.5*	18.6*	Inherent/ Obvious	Aug. 1995
611	T0419	55**	19.8**	Inherent/ Obvious	June 1995
664	Sample 4	39-66	16-21	Inherent/ Obvious	April, 1994
673	T0419	54**	20**	Inherent/ Obvious	Feb., 1996
748	R121x	60*	18.1*	Inherent/ Obvious	Jan, 1996
784-85	R1217	63	18.4*	Inherent/ Obvious	Jan, 1996
1658-59	Uniweb	54	16.9	Inherent/ Obvious	Dec., 1994
1660	Securon	39-66	15-21	Inherent/ Obvious	April, 1994
1661-62	Securon	51-61	15-18	Inherent/ Obvious	Aug., 1994
	Kimguard	39-59	9-15	Inherent/ Obvious	Aug., 1994
	Spunguard	49.6	14.7	Inherent/ Obvious	
1664	Securon 1.8 osy	62.1	14.6	Inherent/ Obvious	June, 1995
	Securon 1.4 osy	59.5	18.1	Inherent/ Obvious	June, 1995
	Securon 1.2 osy	58.3	21.2	Inherent/ Obvious	June, 1995
	Securon 2.1 osy	52.9	16.3	Inherent/ Obvious	June, 1995
1666	Hawk trial	64-69	18-19	Inherent/ Obvious	Dec., 1994
1667	Hawk trial	54.6*	17.9*	Inherent/ Obvious	Jan., 1995
1478	Securon 1.2 osy	54**	18.3**	Inherent/ Obvious	Sept, 1996

DuPont doc. number	Name of fabric	Hydrohead (cm)	Air permeability (m/m)	Void percentage	Date
161318-20	KC SMS	68.5-71	11.4-14.1	Inherent/ Obvious	1995

The above examples demonstrate that BBA, Kimberley-Clark, and others commercially manufactured fabrics which anticipated claim 4 of the '909 patent. Because of the high air permeability of these examples, and the preceding discussion, each of these fabrics has a void percentage of above 85%.

These examples, therefore, also anticipate claim 64 as it depends on claim 4 as anticipated by inherency.

Also, using the teachings of the prior art, and the other patents, and other techniques well known in the art, it would be obvious to one of skill in the art to vary the manufacturing parameters to attain the combination of properties in claim 64 as it depends on claims 4 and 5 of the '909 patent.

v. Other considerations

Changing a fabric to increase particular properties, of course, involves trade-offs with many other properties which end-users find essential (such as wear, comfort, or price), but if a person of skill in the art in the mid-1990s were willing to make those tradeoffs, achieving the properties claimed by the patent in claims 4, 5, and 64 would present absolutely no problem to him or her.

Additionally, DuPont's construction of "at least about" seems to cover numbers which go well below and above the claimed values. According to the above prior art references, if DuPont's construction is adopted, the resultant more expansive meaning of about will mean that more prior art references will anticipate claim 64, regardless of an inherency analysis. In any case, the references cited

above anticipate claim 64 as to both claims 4 and 5 because void percentage is an inherent characteristic of nonwovens related to air permeability.

Finally, the claims of many prior art references cover fabrics with a hydrostatic head and air permeability well in excess of those in the claims asserted in the '909 patent, because they do not specify an upper limit for their claimed ranges. See '035 patent, claim 2 (claims "at least" 40 cm and less than 91.4 m/m); '753 patent, claims 15-16 (claims "about 40" to "about 90" cm; it is inherent that the air permeability is over 1 m/m); '751 patent; claims 10-12 (claims "at least" 15 cm and "at least" 15 m/m). For this reason also, the claims of these prior art patents anticipate claim 64, as it depends on claims 4 and 5 of the '909 patent.

C. MARKUSH CLAIM INVALIDITY (Claim 5)

I am informed that a Markush claim is one, such as claim 5, where a group of alternative subgroups are listed, and the claim covers each of the members of the group. Each alternative is a substitution for the other alternative in the claim. I am also informed that where one subgroup Markush claim is invalid over prior art, the entire claim is invalid. *See Upsher-Smith Labs., Inc. v. Pan Am. Labs., Inc.*, 2003 U.S. Dist. LEXIS 22980, No. 01-352 ADM/AJB at *15. (D. Minn. Dec. 19, 2003) (invalidating Markush group claim "because the prior art need only anticipate one of the claim's four variations to invalidate the entire claim."); *see also In re Skoll*, 523 F.2d 1392, 1397 (C.C.P.A. 1975) ("So long as any one of the items in the group is not patentably distinct over an earlier issued patent, the entire Markush group is invalid as a matter of law."); *Ecolechem, Inc. v. So. Cal. Edison Co.*, 1996 U.S. App. LEXIS 13330 (Fed. Cir. 1996); *Schering Corp. v. Geneva Pharm., Inc.*, 339 F.3d 1373, 1380 (Fed. Cir. 2003).

The third alternative combination in claim 5 has the properties of an air permeability of 15 m/m and a hydrostatic head of 40 cm. These are the same properties as claim 4,[8] which is clearly anticipated based on the prior art, as I have described in the analysis of the references above. Therefore this third subgroup is invalidated as anticipated by the prior art.[9] Since at least the third subgroup is invalid for anticipation, the entire claim is invalid. Moreover, claim 64 is therefore invalid to the extent that it depends on claim 5.

X. INVALIDITY UNDER 35 U.S.C. § 112

A Lack of Enablement of claim 64

Based upon my reading of the '909 patent, specifically, the descriptions of example 1-37, and the related data, and a corresponding document DNW0162239, which I understand to be corresponding data to some of the examples cited in the '909 patent, I understand these samples were made on a laboratory bench top. (Col. 6, line 39-col. 8 line 40). They were probably made using a method such as a hand-forming technique, perhaps the TAPPI Rapid Method. This type of method involves dispersing a given weight of pre-cut fiber in a mixing device, mixing the fiber with a liquid, pouring the resultant dispersed slurry onto a boxed screen, agitating the box to obtain a fiber lay-down, and subsequently removing the thus formed fabric (also called a handsheet). The patent specifies that polyethylene fibers were cut to 5 mm. (Col. 6, line 40). The handsheet can then be bonded by heat, pressure, or chemical binder application, and then conditioned for testing. The

[8] Although the claims may be distinguished by the words "unsupported" (which only claim 5 has) and "about" (which only claim 4 has for air permeability), these differences are insubstantial in view of the prior art. See footnote 7.

[9] The other subgroups from claim 5 could be invalidated in this manner, but it sufficient for this argument that only one subgroup be invalidated.

fabrics in examples 1-37 used an acrylic binder. (Col. 6, line 42). Handsheets made in this fashion do not have the uniformity representative of a commercial wet-lay nonwoven manufacturing process, and consequently will vary in thickness and uniformity of properties.

The data contained on DNW0162239-240 correspond exactly to examples 20-25 and 32-37 in the '909 patent. This indicates that each example in these groups was taken from one section of a fabric, or handsheet, and each group, such as 20-25 actually represent various measurements taken from a single handsheet. These tests were apparently to test the effects of different fiber diameters on the hydrostatic head and air permeability properties of the resultant fabric. The results are different because a handsheet made in the lab will vary substantially in thickness from one spot to another.

Individual examples do not represent different fabrics, but are individual samples taken from the same fabric. The patent appears to have five different batches represented. Examples 1-13, 14-19, 20-25, 26-31, 32-37 are apparently groups of samples from individual batches. Individual numbers from a particular example do not reflect the properties of each fabric made. The numbers have to be averaged to create at least a minimally meaningful idea of the properties of the fabric created by the wet-lay process. The '909 patent calls each data point from each fabric as representative of an "example," when they would more accurately be described as individual test results.

The average values are as follows:

Examples	Frazier (m/m)	Hydrostatic Head (cm)	Void %
1-13	39.9	41.1	92.4
14-19	56.8	33.8	91.2
20-25	5.9	74.1	81.0

26-31	20.7	30.1	86.3
32-37	29.8	35.8	86.6

Because none of fabrics cited in the patent explain how to achieve a hydrohead of 80 cm and a Frazier permeability value of 1 m/m, with a void percentage of 85%, as set forth in claim 64, the patent is invalid under the "written description" requirement 35 U.S.C. § 112.[10] The patentee had not demonstrated to the Patent Office that the patentee had actually practiced what it claimed. Whether intentional or not, listing the individual test results as "examples" was somewhat misleading. This deficiency in the written description is enough to render the claim invalid under 35 U.S.C. § 112.[11]

B. Lack of enablement for the claimed ranges

As asserted by DuPont, claim 64 of the '909 patent claims to cover, with respect to Frazier permeability and hydrostatic head, combinations of: (a) "Frazier permeability of at least 1 m/m" with "hydrostatic head of at least about 80 cm" and (b) "Frazier permeability of at least about 15 m/m" with "hydrostatic head of at least about 40 cm." These ranges have no upper limit, and I am told that DuPont's proposed construction of these terms provides no upper limit. The patent, however, does not disclose how to achieve such a range with no upper limit. If, for example, the 1/80 combination is construed to have no upper limit, such that it includes air

[10] In fact, none of the individual test results show the combination which is claimed in claim 64. The only test result which has a hydrostatic head over 80 cm, Example 23, has a void percentage of 77%. The next closest, Example 24, with a hydrohead of 77 cm, has a void percentage of only 81%.

[11] Examples 38-42 were not considered because these do not disclose the void percentage or any means of calculating the void percentage. It may be argued that examples 38-42 enable claim 64 by inherency because of their high air permeability. However, if void percentage can be measured by air permeability, the claims of the patent are anticipated or obviated by all the prior art above listed above, and the inequitable conduct claim referred to earlier would be come much stronger.

permeabilities of 10, 15 m/m or greater, while maintaining a hydrostatic head of at least about 80 cm, and the court finds that the above prior art does not anticipate or render claim 64 obvious, then claim 64 cannot be enabled.

In am informed that the Federal Circuit has found that "when a range is claimed, there must be reasonable enablement of the scope of the range." *AK Steel Corp. v. Sollac and Ugine*, 344 F.3d 1234, 1244 (Fed. Cir. 2003). In view of the previous discussion which points out that the patent does not disclose how to achieve a fabric with an air permeability of 1, a hydrohead of 80, and a void percentage of 85%, the patent surely does not disclose a fabric with values higher than these, such as a hydrohead of 80 cm and an air permeability of 10 m/m.

Examples 20-25 teach a fabric with a hydrohead of 74 cm, a Frazier of 6 m/m, and a void percentage of 81%. Because hydrohead generally increases if air permeability and void percentage decrease, and vice versa, if the patent does not even teach a 80 cm, 1 m/m, 85% fabric, the fabric cannot teach a fabric with even greater values. Were the hydrohead to increase, the void percentage and the air permeability would decrease. Certainly, one skilled in the art could do some experimentation to improve the air permeability and hydrostatic head to some degree, but the prior art is closer to the claimed ranges than are the examples in the patent. If for some reason the court finds that claim 64 not anticipated or rendered obvious by making slight adjustments to the prior art, then claim 64 cannot be enabled, because much of the prior reads on the claims of the '909 patent better than do the examples in the '909 patent.

XI. DEMONSTRATIVES

I reserve the right to use demonstratives, such as animations, to assist me in explaining my opinions and assist the Court and jury in understanding them.

XII. ADDITIONAL OR AMENDED OPINIONS

I reserve the right to augment or amend my opinions in the event that I become aware of new or different information, including prior art, or in the event that the Court provides additional or different claim constructions.

XIII. DECLARATION

In compliance with 28 U.S.C. §1746, and the laws of the State of South Carolina, I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge. Executed in Clemson, South Carolina, this 29th day of April, 2005.

Edward Vaughn
Edward Vaughn

APRIL 29, 2005
Dated:

CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the foregoing has been served upon the following on this 29th day of April, 2005 via:

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EXHIBIT A

RESUME

Edward Allen Vaughn

PERSONAL DATA

Professor
School of Materials Science and Engineering
Clemson University
Clemson, SC 29634-0971
(864) 656-5965

May 26, 1940
Youngstown, OH
USA

EDUCATION

Ph.D., University of Manchester, 1969, Fiber Physics
M.S., Institute of Textile Technology, 1964, Textile Technology
B.S., Lynchburg College, 1962, Physics and Mathematics

PROFESSIONAL REGISTRATION

Fellow, The Textile Institute, Manchester England, 1989
Chartered Textile Technologist, The Textile Institute, Manchester England, 1970

PROFESSIONAL EXPERIENCE

Clemson University, 1979 - , Professor
Clemson University, 1977 – 1989, Director, School of Textiles
Clemson University, 1973 – 1979, Associate Professor
Clemson University, 1969 – 1973, Assistant Professor
Clemson University, 1967 – 1969, LWOP
Clemson University, 1966 – 1967, Instructor
University of Manchester, 1967 – 1969, Laboratory Demonstrator
Institute of Textile Technology, 1964 – 1966, Research Associate

CONSULTING EXPERIENCE

INDA, Association of the Nonwoven Fabrics Industry, Cary, NC (1989 -), Nonwoven Fabric Technology and Markets.

Wood, Herron & Evans, LLP., Cincinnati, OH (2001), Nonwoven fabric product and process patent analysis.

Alston & Bird, LLP., Charlotte, NC (2001), Diaper patent analysis.

Milliken and Company, Spartanburg, SC (1999), Nonwoven fabric processing technology analysis.

M-Tec Corporation, North Charleston, SC (1998), Industrial fabric manufacturing plant productivity assessment.

Card-Monroe Corporation, Chattanooga, TN (1997), Carpet tufting patent analysis.

Paragon Trade Brands, Inc., Atlanta, GA (1997), Diaper patent analysis.

Aircraft Braking Systems Corporation, Akron, OH (1997), Carbon fiber processing methodology.

YKK (U.S.A.), Inc., Macon, GA (1997), Nonwoven fastener product design.

Finnegan, Henderson, Farabow, Garrett & Dunner, LLP., Washington, DC (1996), Synthetic fiber manufacturing patent analysis.

Irell & Manella, LLP., Los Angeles, CA (1994), Diaper patent analysis.

Ashworth Bros., Inc., Greenville, SC (1994), Carding machinery design assessment.

MEMBERSHIPS

Associate, INDA, Association of the Nonwoven Fabrics Industry, (1994 -)
Fellow, Textile Institute, FTI & C-Text (1989 -)

PUBLICATIONS

Books and Monographs

"Mechanical Properties of Fibers and Fiber Assemblies," J.W.S Hearle and E.A. Vaughn in Polymer Science, A. Jenkins, Ed., (North Holland Publishing Company, Amsterdam, London, 1972).

The U.S. Textile Mill Products Industry: Strategies for the 1980's and Beyond, Center for Industry Policy and Strategy, Division of Research, College of Business Administration, University of South Carolina, October 1983; Chapter 3 "Technological Developments in the Textile Mill Products Industry," Clarence D. Rogers and E. A. Vaughn.

"Nonwoven Fabrics," E.A. Vaughn, Encyclopedia of Materials Science and Engineering, M.E. Bever, Editor, Permagon Press, 1986.

"Present and Future Fiber Requirements," E.A. Vaughn in The Technical Needs. Nonwovens for Medical/Surgical and Consumer Uses, Donald F. Durso, Ed., (Tappi Press, Atlanta, 1986).

Nonwovens World Factbook 1991, Vaughn, Edward A., (Miller Freeman Publications, San Francisco, 1990).

"Present Status and Future Needs of High-performance Fibers for Nonwovens," E.A. Vaughn in Fibers and Forming for Nonwovens A TAPPI Press Anthology of Published Papers, 1985-1991, Matthew J. Coleman, Ed., (Tappi Press, Atlanta, 1992).

Nonwoven Fabric Primer and Reference Sampler, E. A. Vaughn, (INDA, Cary, N. C., 1992).

"Nonwoven Processes and Products," E. A. Vaughn in Polyester: 50 Years of Achievement, Hearle and Brunnschweiler, eds. (The Textile Institute, Manchester, 1993).

"Nonwoven Fabrics, Staple Fibers," E. A. Vaughn, in Kirk-Othmer, Encyclopedia of Chemical Technology, Fourth Edition, Volume 17 (John Wiley & Sons, Inc. 1996). Reprinted in the Fifth Edition, 2004.

Nonwoven Fabrics Sampler and Technology Reference, E. A. Vaughn, (INDA, Cary, N. C., 1998).

Refereed Journal Publications

"Fatigue Studies of Drawn and Undrawn Fibre Materials," J.W.S. Hearle and E.A.Vaughn, Rheologica Acta, 9, (1), 76 (1970).

"Preparation of Fiber Cross-Sections for Studying Dye Diffusion," E.S. Olson, E.A. Duffy and E.A. Vaughn, American Dyestuff Reporter, March, 1972.

"Some Promising Methods of Staple Yarn Production," E.A. Vaughn, Clemson University Review of Industrial Management and Textile Science, 1974.

"Education's Input to Nonwovens," E.A. Vaughn, Formed Fabrics Industry, 5, (11) 56 (1974).

"The Effects of Temperature and Tension on the Structure of False-Twist Textured Polyester," E.A. Vaughn and H.P. Maynard, America's Textiles/Reporter Bulletin, April 1975.

"Overview of Nonwoven Technology," F.T. Simon and E.A. Vaughn, Clemson University Review of Industrial Management and Textile Science, 1975.

"Major Milestones in Weaving Technology," E.A. Vaughn, Clemson University Review of Industrial Management and Textile Science, 1975.

"The Effect of Certain Machine Parameters and Fiber Preparation on the Properties of Open - End Cotton Yarns," E.A. Vaughn and T. Hiranpreuck, Journal of Engineering for Industry, 98, (B No. 2), 670 (1976).

"The Effects of Opening Roller Wire Design and Operating Speed on the Properties of Open - End Cotton Yarn," E.A. Vaughn and T.S. Cox, Journal of Engineering for Industry, 98, (B No. 2), 664 (1976).

"Cotton Fiber Properties and Quality of Open - End Yarn," E.A. Vaughn and C.K. Bragg, Transactions of the ASQC, Textile and Needle Trades Division, 4, 49 (1976).

"The Effects of Fiber Properties and Preparation on Trash Removal and Properties of Open - End Cotton Yarns," E.A. Vaughn and J.A, Rhodes, Journal of Engineering for Industry, 99, (B No. 1), 71 (1977).

"Some Promising Methods of Staple Yarn Production," E.A. Vaughn, Philippine Textile Information Digest, Philippine Textile Research Institute, Volume VII: 14, 1977.

"Prediction of Fabric Hand From Mechanical Properties of Woven Fabrics," C.J. Kim and E.A. Vaughn, Journal of the Textile Machinery Society of Japan, Vol.32, No.6, T47-T59, 1979.

"Fiber Migration and Characteristics in Open - End Spun Cotton-Rich Blended Yarn," H.M. Behery, E.A. Vaughn and M. Lee, Transactions of the ASME, 102 67 - 72 (February, 1980).

"Manufacturing Methods and Product Applications for Nonwovens," E.A. Vaughn, Textile Marketing and Technology, 28 - 31, (December, 1984).

"Applications of Nonwovens," Part II, E.A. Vaughn, Textile Marketing and Technology, 30, (February, 1985).

"The Impact of HVI Technology on Cotton Spinning," Part I, C.D. Rogers, E.A. Vaughn, Textile Marketing and Technology, 22 - 25, (June, 1985).

"The Relationship of Textile, Paper, and Plastic Technologies to Emerging Nonwoven Manufacturing Processes," E.A. Vaughn, Journal of Coated Fabrics, Vol. 18, 94-105, October 1988.

"Highloft Nonwovens: A Difficult Market to Define," Edward Vaughn, Nonwovens Industry, Vol. 20, No. 5, 22-26, May 1989.

"Highloft Nonwovens: A Definition of the Market," E. A. Vaughn, Journal of Nonwovens Research, Vol. 1, Number 1., 1989.

"Textile and Polymer Based Nonwoven Technologies: Current Status and Recent Developments in the US and Their Relationship to Traditional Paper Based Nonwovens," Vaughn, E.A., Annals of the High Performance Paper Society, Japan, No. 28, November, 1989.

"Nonwovens as Substrates for Coated Fabrics," E. A. Vaughn, Journal of Coated Fabrics, Vol. 21, 156-179, Jan. 1992.

"Historic Needlpunch Developments," E. A. Vaughn, Journal of Nonwovens Research, Vol. 4, Number 1., 1992.

"75 Years of Change in the American Textile Manufacturing Industry," J. Richard Aspland and Edward A. Vaughn, Textile Chemist and Colorist, 25-27,Vol. 29, No. 5 (May 1997).

"Expanded Surface Area Fibers: A Means for Medical Product Enhancement," Edward A. Vaughn and Brent G Carman, Journal of Industrial Textiles, Vol. 30, No. 4, April, 2001.

"Fiberglass vs. Synthetic Air Filtration Media," Edward Vaughn and Gayetri Ramachandran, International Nonwovens Journal, Vol.11, No. 3, 41-56, Fall 2002.

Conference Proceedings (Reviewed)

"Fundamentals of Fabric Hand: The Problem of Objective Measurement of a Subjective Phenomenon," E.A. Vaughn and C.J. Kim, Nonwoven Product Technology - Materials, Processes & Evaluation, (INDA, New York, 1973).

"The Effects of Cotton Fiber Properties on the Quality of OE Yarns," E.A. Vaughn, Open - End Spinning and Its Implications for Cotton, (National Cotton Council, Memphis, 1975).

"Definition and Assessment of Fabric Hand," E.A. Vaughn and C.J. Kim, Proceedings of the 1975 National Technical Conference of the American Association of Textile Chemists and Colorists. AATCC (Research Triangle Park, N.C., 1975).

"Physical Parameters Associated with Fabric Hand," C.J. Kim and E.A. Vaughn, Proceedings of the 1975 National Technical Conference of the American Association of Textile Chemists and Colorists. (Research Triangle Park, N.C. 1975).

"A Study of the Effect of Processing Variables on the Absorption Properties of a Nonwoven Rayon-Cotton Linter Blend," E. A. Vaughn and E. S. Homonoff, Technical Symposium, Nonwovens Technology and Its Application to Market Growth, INDA, Association of the Nonwoven Fabrics Industry, New York, 1978.

"A Dynamic Investigation of the Relationships Among Binder Adhesion, Deformation and Tensile Properties of Polyester Nonwoven Fabrics," R.C. Brannon and E.A. Vaughn, Proceedings of TAPPI, September 1978.

"A Comparison of Foam and Saturate Bonded Nonwovens: Effects of Fiber and Binder Blends," C.W. Jarvis, P.A. Danforth, B.A. Kolinofsky, and E.A. Vaughn, 7th Technical Symposium Papers, INDA, 1979.

"Discrete Models for Nonwoven Fabrics," R.E. Haymond, M.D. Frawley, and E.A. Vaughn, 10th Technical Symposium Papers, INDA, 1982.

"Present Status and Future Needs of High Performance Fibers for Nonwovens," E.A. Vaughn, Proceedings of TAPPI, April 1985.

"Effects of Web Formation Parameters on Thermally Bonded Nonwoven Fabrics," E.A. Vaughn, C.W. Jarvis, and Mario Orozco Arena, 13th Annual Technical Symposium, INDA, New York, June 1985.

"A Study of the Effects of Mechanical and Thermal Consolidation Mechanisms on the Geometry and Filtration Performance of Air Laid Nonwoven Filter Media," E. A. Vaughn, B. C. Goswami, and C. I. Rodriguez, Proceedings of TAPPI, April 1986

"Nonwovens as Reinforcement Media for Composites," T.D. Bayha, E.A. Vaughn, G.C. Lickfield, INDA-TEC 1987, INDA, New York, 1987.

"The Relationship of Textile Paper and Plastic Technologies to Emerging Non-Woven Manufacturing Processes," E. A. Vaughn, The Textile Institute World Conference, Sydney, Australia, 10-13 July 1988.

"Present and Future Markets for Highloft End-Uses," E.A. Vaughn, INDA Highloft Seminar Book of Papers, 21-32 (INDA, New York, 1989).

"Properties and Characteristics of Fibers Used in Needlepunched Nonwovens," E.A. Vaughn, INDA Durable Needlepunch Conference Book of Papers, 41-62 (INDA, Cary, N.C. 1992).

"Fibers for Nonwovens: Technical Applications," E. A. Vaughn, Nonwovens Americas, Mexico '95 Exposition and Conference Book of Papers, (INDA, Cary, NC. 1995).

"Nonwoven Markets and Technologies: The Americas," E. A. Vaughn, Nonwovens Americas, Mexico '95 Exposition and Conference Book of Papers, (INDA, Cary, NC. 1995).

"Nonwoven Process and Products Applicable to Cotton and Other Cellulosic Fibers," E. A. Vaughn, Proceedings of the 1999 Beltwide Conference (National Cotton Council, Memphis, January 1999)

"Nonwovens – The Route to Millennium Fabric Magic," E. A. Vaughn, Proceedings of the 2000 Beltwide Conference (National Cotton Council, Memphis, January 2000)

"Acoustical Insulation of Nonwoven Fabrics," E. Vaughn, and M. Tascan, Proceedings of the 2003 Beltwide Conference (National Cotton Council, Memphis, January 2003)

Conference Proceedings (Unreviewed)

"Recent Developments in Weaving," E.A. Vaughn, Proceedings of the Southern Textile Association, (Clemson, 1974).

"Current Trends in Fiber Preparation," E.A. Vaughn, Proceedings of the Southern Textile Association, (Clemson, 1975).

"A Dynamic Study of Relative Binder Effectiveness in Dry Laid Polyester Nonwovens," E.A. Vaughn and R.C. Brannon, Nonwoven Technology – The Merging of Multiple Technologies, (INDA, New York, 1977).

"Analysis of Surgical Sponges for Lint," R.B. Stanford, B. Stanford, and E.A. Vaughn, Nonwoven Technology - The Merging of Multiple Technologies, (INDA, New York, 1977).

"An Overview of Current Highloft Markets," E. A. Vaughn, INDA Highloft Conference Book of Papers, insert (INDA, Cary, N.C. 1993).

"Other Fibers for Highloft," E. A. Vaughn, INDA Highloft Conference Book of Papers, (INDA, Cary, NC 1995).

"Nonwoven Fabric Enhancement Overview," E. A. Vaughn, INDA-TEC '97. (INDA, Cary, NC 1997)

Research Reports

"Survey of Cost, Quality, Production, and Waste in Print Cloth Manufacturing Processes Among Institute Member Mills," F.P. Purvis and E.A. Vaughn, I.T.T. Confidential Res. Rpt. No. 116, Charlottesville, Virginia, (1964).

"Survey of Cost, Quality, Production and Waste in Mills, Second Quarter, 1964," F.P. McKenna, W.C. Harris, C.K. Bragg, G.B. Peeler, W.J. Purvis, and E.A. Vaughn, I.T.T. Confidential Res. Rpt. No. 117, Charlottesville, Virginia, (1965).

"Survey of Practices and Procedures Currently Being Used in Twenty – eight Institute Member Mill Cloth Rooms," E.A. Vaughn and F.P. McKenna, I.T.T. Confidential Res. Rpt. No. 125, Charlottesville, Virginia, (1966).

Other Scholarly Publications

"Staple Spinning: After the Ring, What?," E.A. Vaughn, Textile World, 126, (10) 115 (1976).

"The Loom Shows Its Growing Strength," E.A. Vaughn, Textile World, 126, (10) 102 (1976).

"Spunlaced Fabrics," E.A. Vaughn, Canadian Textile Journal, Canadian Textile Journal Publishing Company, Ltd., Quebec, Canada, Vol. 95, No. 10, October, 1978.

"Quality Aspects of Cotton-Rich Blended Open End Yarns," E.A. Vaughn and M.S. Lee, American's Textiles, April 1979.

"Perspective on Fiberfill," E.A. Vaughn, Nonwovens Industry, 12, (2), 8 - 10, 1981.

"Polymer - Laid Fabrics: The Third Dimension in Nonwovens," E.A. Vaughn, Fiber World, Volume 11, No. 3, June 1984.

"Thermal Bonding," E. A. Vaughn, Fiberfill and Other Highloft End-Uses, INDA, New York, 1987.

"Nonwovens Technology Italian Style," Edward A. Vaughn, America's Textiles International, Vol. 20, Number 6., 77-83, June 1991.

"An Evaluation of the Effects of Various Management Strategies on Profits Relative to the Cotton Broad Woven Goods Economic Cycle," E.A. Vaughn, M.S. Thesis, Institute of Textile Technology, Charlottesville, Virginia, (1964).

"On the Fatigue Properties of Textile Fibres," E. A. Vaughn, Ph.D. Thesis, The Victoria University of Manchester, Manchester, England (1969).

PRESENTATIONS

E.A. Vaughn, "Seminar on the U.S. Cotton Industry," presented in Osaka, Japan; Taipei, Taiwan; Hong Kong, B.C.C.; Manila, Philippines; Bangkok, Thailand; and Bombay, India, (Summer 1973).

E.A. Vaughn, "Cotton Fiber Requirements for Open - End Spinning," presented at Textile Operating Executives of Georgia, Fall Workshop; Atlanta, Georgia, (September 1975).

E.A. Vaughn and T.D. Efland, "Weaving is Secure," presented at the Draper Worldwide Marketing Conference, Rome, Italy, (October 1975).

E.A. Vaughn, "Seminar on U.S. Cotton and Open - End Spinning," presented in Taipei, Taiwan; Hong Kong, B.C.C.; Manila, Philippines, (Summer 1976).

E.A. Vaughn, "Basic Concepts of Nonwoven Fabrics," presented at the IDEA 78, International Nonwovens Exposition, Chicago, Illinois, (October 1978).

E.A. Vaughn, "Recent Innovations of Nonwovens," presented at the Gulf Coast Section of American Association of Textile Chemists and Colorists, New Orleans, Louisiana, (March 1979).

E.A. Vaughn, "The Nonwoven Fabrics Industry, Its Current, Technical, Marketing and Test Standardization Status," American Society for Testing and Materials, Charlotte, North Carolina, (March 1980).

E.A. Vaughn, "Fiber - Fabric Relationships in Today's Nonwovens," presented at the 18th Annual Spring Seminar of the Appalachian and Piedmont Chapters of the American Association for Textile Technology, Gatlinburg, Tennessee, (May 1980).

E.A. Vaughn, "Basic Concepts of Nonwoven Fabrics," presented at IDEA 80, International Nonwovens Exposition, Chicago, Illinois, (October 1980).

E.A. Vaughn, "Overview of the U.S. Fiberfill Industry," presented at INDA's First Fiberfill Conference, Atlanta, Georgia, (January 14, 1981).

E.A. Vaughn, "Fibers for Fiberfill," presented at INDA's First Fiberfill Conference, Atlanta, Georgia, (January 15, 1981).

E.A. Vaughn, "Nonwovens in Textile Education," panel presentation before the Technical Symposium, "Nonwovens in the 80's: Years of Change," Atlanta, Georgia, (March 10, 1981).

E.A. Vaughn, "Basic Concepts of Nonwoven Fabrics," presented at IDEA 82, International Nonwovens Exposition, (October 1982).

E.A. Vaughn, "Fiberfill Bonding Update," presented at the Fiberfill Advances in Furniture Seminar, Charlotte, N.C., (March 7- 9, 1984).

E.A. Vaughn and C.D. Rogers, "The Use of High Volume Instrument Technology to Enhance Yarn Manufacturing Performance and Product Quality," presented at joint Mini - Conference, East China Institute of Textile Science and Technology, Clemson University; Shanghai, People's Republic of China, (April, 1984).

Ryan C. Amacher, Clarence D. Rogers, and E.A. Vaughn, "The United States Textile Industry," presented at joint Mini-Conference, East China Institute of Textile Science and Technology, and Clemson University; Shanghai, People's Republic of China, (April 1984).

E.A. Vaughn, "Current Directions in Nonwoven Manufacturing Technology and Product Applications in the United States," presented at joint Mini--Conference, East China Institute of Textile Science and Technology, and Clemson University; Shanghai, People's Republic of China, (April 1984).

E.A. Vaughn, "Discrete Model of the Geometry of Nonwoven Fabrics," presented at the Fiber Society Technical Conference on Fiber Processing and Properties, University of Tennessee, (October 10-12, 1984).

E.A. Vaughn, "Basic Concepts of Nonwoven Fabrics," presented at the Seventh International Exposition and Conference, INDA, Association of the Nonwoven Fabrics Industry, (October 16-18, 1984).

E.A. Vaughn, "Models of Textile Fiber Networks," presented at the University of Rhode Island Mechanical Engineering and Applied Mechanics Seminar Program, (April 22, 1986).

E.A. Vaughn, "Current Status and Future Prospects for Nonwoven Fabrics," presented at the National Meeting of The American Association for Textile Technology, (March 14, 1986).

E.A. Vaughn, "Basic Concepts of Nonwoven Fabrics," presented at IDEA 86, International Nonwovens Exposition Conference, INDA, Association of the Nonwoven Fabrics Industry, (October 21-23, 1986).

E.A. Vaughn, "The Relationship of Textile, Paper, and Plastic Technologies to Emerging Nonwoven Manufacturing Processes" presented at the Textile Institute World Conference, Sydney, Australia, (July 1988).

E.A. Vaughn, "Basic Concepts of Nonwoven Fabrics," presented at IDEA 88, International Nonwovens Exposition Conference, INDA, Association of the Nonwoven Fabrics Industry, Baltimore, Maryland, (October 1988).

E.A. Vaughn, "Present and Future Markets for Highloft End-Uses," presented at the INDA Highloft Seminar, Durham, N.C., (March 14, 1989).

E.A. Vaughn, "Overview of Textile Education in the U.S.," presented at CIETEX-89 International Meeting of Textile Educators, Clemson, S.C., (April 13, 1989).

E.A. Vaughn, "Fiber Requirements for Present and Future Nonwoven Fabrics," presented at the Japan Nonwoven Producers Technical Conference, Osaka, Japan, (November, 1989).

E.A. Vaughn, "Nonwoven Process and Product Fundamentals: Production Methods, Performance Features, End-use Examples," presented at IDEA-90, International Nonwovens Conference and Exposition, INDA, Association of the Nonwoven Fabrics Industry, (September 25-27,1990).

E.A. Vaughn, "Historic Needlpunch Developments," presented at INDA Needlepunch-90, Charlotte, N. C., (December 4-5, 1990).

E.A. Vaughn, "Properties and Characteristics of Fibers Used in Needlepunched Nonwovens," presented at INDA Durable Needlepunch Conference, Charlotte, N. C., (March 17-18, 1992).

E.A. Vaughn, "Nonwoven Basics" presented at IDEA-92, International Nonwovens Conference and Exposition, INDA, Association of the Nonwoven Fabrics Industry, (November 17-19,1992).

E.A. Vaughn, "End-Use Markets for Highloft Nonwovens," presented at the INDA Highloft Conference, Charlotte, N.C., (May 18, 1993).

E.A. Vaughn, "Fundamentals of Nonwoven Technologies," presented at INDA - TEC 93, 94, and Nonwovens Americas, (Mexico 1995).

E.A. Vaughn, "Nonwoven Fabric Enhancement Overview," presented at INDA- TEC '97 Basics Course.

R. Broughton and E. A. Vaughn, "Nonwoven Basics," presented at INNOTEC 2000.

E.A. Vaughn, "Clemson University's Capillary Surface Materials," presented at the AATCC Piedmont Region fall conference, Greenville, SC, (October 2000), the Fiber Producer's Conference, Greenville, SC, (October 2000), and the Glotex Seminar, Spartanburg, SC (December, 2000).

E.A. Vaughn, "Nonwoven Fundamentals Shortcourse," presented at IDEA 2001.

E.A. Vaughn, "Nonwoven Process and Product Fundamentals," presented at INDA Nonwoven Training Courses, Cary, NC, (once per quarter, 2002, 2003, 2004).

E.A. Vaughn, "Nonwovens Technology Overview," presented at INDA Product Development Programs, Cary, NC, (2002, 2003, 2004).

E.A. Vaughn, "Nonwoven Consumer Products," presented at the INDA Vision 02 and Vision 03 Conferences, New Orleans, LA, (January 2002 and January 2003).

E.A. Vaughn, "Fiberglass V. Synthetic Air Filtration Media", presented at 2002 National Air Filtration Association Technical Seminar Program, Nashville, TN, (April 2002).

E.A. Vaughn, "Nonwoven Formation," presented at Nonwovens Enhancements Coloring & Finishing Conference, Raleigh, NC, (June 17-19, 2003).

E.A. Vaughn, "Nonwoven Basics," presented at INDA Vision 04 Conference, Las Vegas, NV (January 2004).

E.A. Vaughn, "Fabric Basics," presented at IDEA 04, Miami Beach, FL, (April 2004).

PATENTS

"Formation of Nonwoven Webs or Batts from Continuous Filament Tow or Yarn Strands," U.S., 4,514,880.

"Multi-Layer Pleated Textile Fiber Product," U.S., 4,576,853, Michael L. Clymin.

"Fiber Reinforced Composites and Method for Their Manufacture," U.S., 4,663,225, Radcliffe W. Farley, Clarke A. Rodman, and Edward C. Homonoff.

"Method of Manufacture of Formed Article," U.S., 4,812,283, Radcliffe W. Farley, Clarke A. Rodman, and Edward C. Homonoff.

HONORS AND AWARDS

Best Paper Award, ASQC Textile and Needle Trades Division 1976 Technical Conference (1976).

Certificate of Merit, Allied Automotive (1985).

Chairman's Award, INDA Association of the Nonwoven Fabrics Industry (1988).

Mark Hollingsworth Award, Technical Association of the Pulp and Paper Industry (2002)

Teacher of the Year, Phi Psi (2003).

SPONSORED RESEARCH

"The Use of Instrumental Analysis to Determine Quality Characteristics and Processing Performance of Reclaimed Fiber Mixtures," National Textile Center, Co-Principal Investigator, $152,219, (1993 – 1994).

"Assessment of Performance of New Generation BASF Fibers," BASF Corporation, Co-Principal Investigator, $71,202, (1994 – 1995).

"Assessment of Performance of Developmental Conjugate Fibers in Traditional and Developing Textile and Nonwoven Product Applications," Phibril Corporation, Co-Principal Investigator, $79,154, (1996 – 1997).

"Assessment of Performance of Developmental Conjugate Fibers in Traditional and Developing Textile and Nonwoven Product Applications," Fiber Innovation Technologies, Co-Principal Investigator, $79,154, (1997 – 1999).

"Improved Fiber Hydroentanglement Using Pulsed Elliptical Jets," National Textile Center, Co-Principal Investigator, $173,789, (1998 - 2001).

OTHER SPONSORED ACTIVITY

Intellectual Property Donation, Eastman Chemical Company, $38,000,000.00, (2000 -)
Intellectual Property Donation, Proctor & Gamble, $ Undisclosed, (2001 -).

GRADUATE STUDENT ADVISING

Doctoral Graduates

Kim, C.J., "A Study of the Physical Parameters Related to the Mechanics of Fabric Hand," (May 1975).

Brannon, R.C., "The Development of an Integrated Intensity Technique and Its Application in Determining the Crystal Structure of Fibrous Materials," (December 1979).

Masters Graduates

Maynard, H.P., (MS) "Effects of Temperature and Tension in False-Twist Texturing on the Structure of Polyester Fibers," (May 1973).

Chang, C-H.H., (MS) "A Study of the Relationships Among Fiber Properties, Yarn Structures, and Yarn Tensile Properties for Yarns Spun Blends of Polyester and Cotton," (May 1973).

Anno, T., (MS) "An Investigation and Computer Simulation of the Viscoelastic Tensile Behavior of Spandex Yarns," (May 1974).

Giorges, T., (MS) May 1974.

Patankar, J.G., (MS) "A Study of the Effects of Textile Processing on the Tensile Properties of Polyester Yarn," (May 1974).

Cox, T.S., (MS) "An Investigation of the Effects of Comber Roller Wire Design and Comber Roller Speed on Yarns Made from A Selected Cotton Blend," (December 1974).

Hiranpruek, T., (MS) "The Effects of Draft, Turbine Speed, Static Pressure, and Fiber Preparation on Yarnn Physical Properties," (May 1975).

Rhodes, J.A., (MS) "An Investigation of the Effects of Fiber Separation and Trash Removal Slot Opening on the Properties of 16/1 Ne Open-End Yarn Spun from Short and Medium Length Cottons Prepared with Minimum and Maximum Lint Cleaning," (May 1976).

White, W.H.,(MS) "The Effects of Punching Density and Depth of Penetration on the Properties of Needled Fabric," (May 1976).

Lee, M.S., (MS) "A Study of Fiber Migration and Yarn Quality Characteristics in Open-End Spun Cotton/Polyester Blended Yarns," (May 1977).

Brannon, R.C.,(MS) "An Investigation of the Relationships Among Binder Adhesion, Deformation, and Tensile Properties of Dry Laid Polyester Nonwoven Fabrics," (May 1977).

Homonoff, E.S., (MS) "An Investigation into the Effects of Fiber Denier, Fiber Length Distribution, Opening Method, and Fiber Blend Percentage on the Absorption Properties of a Nonwoven Rayon-Cotton Linter Blend," (May 1978).

Alonzo, C.R., (MS) "A Study of the Effects of Mechanical and Thermal Consolidation Mechanisms on the Geometry and Filtration Performance of Aor Laid Nonwoven Fiber Media," (December 1985).

Arena, M.O., (MS) "A study of the Effects of Web Formation Paramerters on the Structure and Properties of Polyester, Dry-Laid, Thermally-Bonded Nonwoven Fabric," (December 1985).

Lloyd, S.A. (MS) "A Standardized Method and Procedure for the Fabrication of Compression Molded Fiberglass Reinforced, Unsaturated Polyester Resin Composite Samples," (August 1987).

Gandhi, M., (MS) "A study of the Physiacl Properties of Hydroentangled Non-Woven Fabrics Formed from Polyester and Rayon Fibers and Polyester, Rayon and Binder Fibers," (August 1992).

Schempp, P., (MS) "A Study of Specific Surface and Related Properties of Nonwoven Filtration Media Produced from High Surface Area Fibers and Their Blends," (August 2000)

Ramachandren, G., (MS) "A Study off the Relationship between Fiber Surface Area and Porometric Properties of Nonwoven Filter Media," (December 2002).

Gray, W.P., (MS) "The Effect of Fiber Type, Yarn Structure, Pick Density, and Pile Ratio on the Physical Properties of Terry Toweling," (May 2003).

Current Graduate Advising

Tascan, M. (PhD), "Acoustical Properties of Nonwoven Fiber Network Structures", (August 2005).

TEACHING

Course Taught

Text 122, Introduction to Textiles, F1970 - 1975
Text 175, Introduction to Textile Manufacturing, F1976 – 2001, F2002 - 2004
Text 176, Natural and Man Made Fibers, S2004
Text 201, Yarn Structures, F2000
Text 202, Fabric Structures, S2003, S2004
Text 301, Yarn Manufacturing I, F1973
Text 302, Yarn Manufacturing II, S1973
Text 305, Natural and Man Made Textile Fibers, S1973, S1974
Text 333, Textile Arts, S1998 - 2001
Text 460, Textile Processes, F2001 – 2002, Su1989, Su1991, Su1992
Text 830, Textile Physics, F1972, F1973
Text 880, Selected Topics, S2001

New Course Development

Text 321, Fiber Science
Text 322, Properties of Textile Structures
Text 324, Textile Statistics
Text 416, Nonwoven Structures
Text 476, Carpet Manufacturing
Text 821, Fiber Physics I
Text 822, Fiber Physics II
Text 835 Yarn Structures I
Text 836, Yarn Structures II

Text 837, Textile Composite Materials
Text 870, Advances in Textile Manufacturing

UNIVERSITY and PUBLIC SERVICE

Continuing Education Programs (Partial Listing)

"Nonwoven Fabrics Forum," Organized and conducted (1970 - 2002, 2004).

"Coated Fabrics," Lecturer (1990 - 2003).

"Narrow Fabrics," Lecturer (1993 – 2002).

"Fundamentals of Textiles," Lecturer twice per year (1989 - 2002).

"Upholstery Fabrics," Lecturer (1997 - 2001).

"Textile Manufacturing Principles, Products and Processes," revised and conducted (1991 - 2001).

Committees

Department: Member, Curriculum Committee (2004 -)
University: Member, Athletic Council (2003 -)

Other Services

Certified Summary Court Judge, City of Clemson (1992 -)

Textile Advisory Committee, Tri County Technical College (1977 -)

Currently serve as collaborative researcher with Dr. Danny Akin, Russell Research Center, ARS-USDA, Athens, GA, on "Creating Nonwoven Fabrics with Specific Properties from Various Flax Fibers and Their Blends."

Currently serve as collaborative researcher with Mr. David McAlister, Cotton Quality Research Station, ARS-USDA, Clemson, SC, on "Fiber Quality Measurements, Processing Efficiency, and End Use Quality."

Served as coeditor for <u>The Airlaid Nonwoven Primer</u>, INDA Association of the Nonwovens Industry (Cary, NC) 2003.

Served as coeditor for <u>INDA Nonwovens Glossary</u>, INDA Association of the Nonwovens Industry (Cary, NC) 2002.

Served as coeditor for The Nonwoven Fabrics Handbook, INDA Association of the Nonwovens Industry (Cary, NC) 1999.

Served as coeditor for The Spunbonded and Melt Blown Technology Handbok, INDA Association of the Nonwovens Industry (Cary, NC) 1999.

MISCELLANEOUS

Professional Association Affiliations and Activities

American Association for Textile Technology, Past Regional Chairman
Textile Quality Control Association, Past President
Southern Textile Association, Member and Former Governing Board Member
Nonwovens Industry, Editorial Advisory Board
C. H. Masland and Sons, Former Corporate Director
National Council for Textile Education, Past President

DATE OF MOST RECENT RESUME UPDATE

August 2004

EXHIBIT B

Nonwovens Technology Primer

an introduction to nonwoven material types and key processes; handy reference guide for basics of nonwovens technology

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Nonwovens are unconventional textile assemblies that are slowly replacing the use of traditional woven/knitted fabrics in household and industrial applications. Nonwovens are defined by INDA, Association of the Nonwovens Fabrics Industry[1], as "sheet or web structures made by bonding and/or interlocking fibers, yarns or filaments by mechanical, thermal, chemical or solvent means." These fabrics do not require the conversion of fibers to yarns and are manufactured by processes other than spinning, weaving or knitting, hence the name "nonwovens." Thus the basic elements of a nonwoven structure are fibers that are either natural or synthetic. Today, various types of nonwovens are being produced that are aimed at meeting specific end uses. The ingenuity in fiber research is being exploited by the nonwovens industry to design functional/aesthetic fabrics ranging from baby diapers to automotive textiles.

The basic nonwoven types can be classified according to the way the webs are produced, as shown in *Table 1*. During the first stage, individual fibers are formed or acquired. A thin web of these fibers is produced in the second stage, which is very weak. A coherent bonded web is produced in the final stage by introducing fiber-to-fiber contacts with appropriate bonding. The differences between woven, paper and nonwoven structures are shown in *Table 2*[2]. The difference in the properties[3] *(Table 3)* between a conventional textile fabric and a nonwoven web is largely dependent on the way they are engineered. The properties of a nonwoven web are dependent on:

— fiber type, diameter and fineness
— fiber strength and elongation
— fiber-to-fiber frictional properties
— fiber geometry and orientation
— chemical properties (functional groups of fibers)
— thermal properties (heat conductivity, melting point, glass transition)
— web formation methods
— types of bonding
— number of bonds and the distance between bond areas
— number of pores, pore sizes and distribution of pores.

Fibers For Nonwovens

The types of fibers used in the nonwovens industry are shown in *Table 4*. All natural[4] and synthetic fibers that are commercially available can be used to produce nonwoven webs. In practice, wood pulp, which is far shorter in length than conventional textile fibers, is the only natural fiber used in large amounts because of its high water absorbency, bulk and low cost. However, cotton has excellent inherent properties for nonwovens. Wool and linen are too expensive for nonwoven fabrics. Viscose rayon has been widely used in the nonwovens industry in the area of disposables and sanitary products. Rayon fibers can be easily made into nonwoven webs and readily bonded.

Among the synthetic fibers, polypropylene (PP) is widely used. Polypropylene is cheap and has very good rheological characteristics to form fine fibers. Polypropylene fibers are hydrophobic, voluminous and thermoplastic in nature. PET (polyethylene terephthalate) is used where strength and mechanical properties are of prime importance Nylon fibers are used for their excellent recovery (resiliency) properties Cellulose acetate and polyvinyl alcohol fibers are used in nonwovens also. Bicomponent fibers with different

Table 1
CLASSIFICATION OF NONWOVEN TYPES

Web Formation	Wet Laid	Dry Laid	Polymer Laid: Spunbonded	Polymer Laid: Melt Blown
Machinery	Modified Papermaking	Carding (mechanical, aerodynamic)	Spinnerette	Horizontal or Vertical Die
Bonding	Chemical (latex) Thermal (calendering	Chemical, Thermal Mechanical (needling)	Thermal, Mechanical	Self Bonded
Fibers	Natural, Rayons (cellulose-based), Short	Natural, Synthetic Staple	Synthetic Continuous Filaments	Synthetic Continuous Filaments

fibers in the core and sheath are widely used in thermally bonded nonwovens.

Web Forming Methods

There are four basic web forming methods as shown in *Table 1*. The selection of a particular method is dependent on the expected end use of the web, availability and cost of fibers. The most widely used web forming methods are wet laid, dry laid and spunbonded. Webs produced should be of superior quality, clean and without any defects (thick and thin places) irrespective of the methods chosen.

Wet Laid. Wet laid nonwovens[5] are produced by a modified paper making process that employs very short fibers (6-12 mm), typically wood pulp and short synthetic or regenerated fibers. There are three main stages in the manufacture of nonwoven bonded fabrics by the wet laid method:

(a) swelling and dispersion of fibers in water; transport of the suspension on a continuous traveling screen

(b) continuous web formation on the screen by filtration

(c) drying and bonding of the web.

Table 2
DIFFERENCES BETWEEN WOVEN, PAPER, AND NONWOVEN STRUCTURES

Woven and Knitted Fabrics—based on yarns interlocking in patterns
Nonwoven Fabrics—based on individual fibers in webs
Papers—based on webs of short cellulose fibers so extensively bonded that most fibers lose their individual identity

Source: "A simplified classification of nonwoven fabrics," Arthur Drelich, Nonwovens Workshop, Aug. 8-19, 1988, The University of Tennessee, Knoxville

Longer fibers[5] may not disperse completely and tend to entangle (flocculate) and form nonuniform sheets. In fact, papermaking machinery has been modified to deal with the problems of removing large amounts of water quickly—without rupturing the sheet as it forms—and controlling fiber orientation in the final product. Wet laid nonwovens are different from paper in the sense that there is no strong hydrogen bond formation as in paper products. High density hydrogen bonding also results in stiff structures, with little or no wet strength, which is not desirable in a textile material. Water disposal (through pressure, vacuum, heat) in the drying stage is the most important step in wet laid process.

Dry Laid. Dry laid webs[6] are produced from staple fibers

Table 3
COMPARISON OF PROPERTIES OF WOVEN AND NONWOVEN FABRICS
(similar area density)

Properties	Woven	Nonwoven
Fiber arrangement	Orthogonal	Random
Properties	Directional	Nondirectional
Breaking Strength	Higher	Lower
Breaking Elongation	Lower	Higher
Initial Modulus	Higher	Lower
Tear Resistance	Lower	Higher
Openings	Can be regular	Irregular
Filtration	Single layer	Often multilayer
Porosity	35% to 45%	55% to 93%
Inplane flow	Low	Can be high
Edge	May ravel	Does not ravel

Source: Raumann, G., "Geotextiles: Construction materials in evolution;" p.10-15, proceedings of Second International Conference on Geotextiles, Aug. 1-6, 1982. Las Vegas, NV.

Table 4
FIBERS USED IN NONWOVEN FABRICS

Major	Minor
Polyester	Nylon
Polypropylene	Cotton
Rayon	Polyvinyl Alcohol
Wood Pulp	Cellulose Acetate
	Polyvinyl Chloride
	Glass
	Acrylic
	Polyethylene

Source: "A simplified classification of nonwoven fabrics," Arthur Drelich, Nonwovens Workshop, Aug. 8-12, 1988, The University of Tennessee, Knoxville

that range from 1.2 to 20 cm long. The fibers from the bales are thoroughly opened and cleaned using conventional openers and beaters. The dry laid webs can be categorized into mechanically (oriented webs) and aerodynamically (random webs) formed webs

Mechanically formed webs are usually produced by carding machines that utilize opposed moving beds of closely spaced needles to pull and tease the clumps apart. When the clumps are caught between two moving surfaces whose surface velocities are quite different from each other, the result is a disentanglement of lumps and individualization of fibers. Modern cards with sophisticated suction systems for dust extraction that can be used to produce clean webs with little nep formation are currently available on the market. Carded webs are predominantly oriented in the machine direction and the strength of the web is typically higher in the machine direction (5:1) than in the cross direction.

To overcome this problem of imbalance in the properties, the cross-laying process can be employed. In this method, an oriented web is laid down at or near [illegible] 45° onto another oriented web moving on a transporting belt. A composite web[7] is the one where webs are laid both longitudinally and cross-wise.

Air laying techniques are used to [illegible] randomly oriented webs. These machines utilize [illegible] web or a lap. The fibers are individualized by [illegible] d then introduced into an air stream. Total ra[illegible] would avoid any preferential orientation when th[illegible] are collected on the screen. The length of fibers is [illegible] 1.9 to 6.4 cm. Production of air laid webs i[illegible] more expensive than that by carding.

Spunbonded. This falls into th[illegible] conversion of polymers into nonwoven w[illegible] nding process would consist of the followi[illegible] of filaments, drawing, lay down and [illegible] three operations are not different from c[illegible] spinning process and the bonding step results [illegible] idation

The filaments formed by this method are virtually endless.

A typical spunbonded line[8] consists of the following elements: an extruder, a metering pump, a die assembly, a filament spinning unit, a drawing and deposition system, a belt for collecting the filaments, a bonding zone and a winding unit. The drawing and deposition of spun filaments in spunbonding is achieved using specially designed aerodynamic devices. The process variables[8] in the process can be classified into operational and material variables. The operational variables can further be classified into on-line variables, such as polymer throughput, polymer/die temperature, quench air rate and temperature, takeup speed or bonding conditions and off-line variables such as spinneret hole size or spinneret-to-collector distance. The material variables include polymer type, molecular weight and molecular weight distribution. The following are some of the important characteristics[8] of a spunbonded web:

— random orientation of fibers (isotropic)
— basis weight ranges from 5-800 gsm
— fiber diameter from 1-50 μm, preferably 15-35 μm
— high specific strength (strength/weight) compared to other nonwovens.

Melt blown. Microfine fibers from bulk polymers can be produced by a Exxon patented one-step process known as a melt blowing process. The molten polymer[4] is forced through very fine holes in a special die into a high velocity air stream where the polymer is formed into very fine, although irregular, filaments of indeterminate lengths. Virtually all thermoplastic polymers can be used to produce melt blown webs. However, polypropylene and polyethylene terephthalate are the most widely used.

Polymer throughput rate[6], air throughput rate, polymer/die temperature, air temperature and die-to-collector distance are important operational variables. The material variables include polymer type, molecular weight, molecular weight distribution and degradation. Some important characteristics[8] of melt blown webs are:

— random fiber orientation
— high cover factor
— fiber diameter of 2-7 μm
— basis weight of 20-200 gsm
— high surface area suitable for insulator and filter characteristics

Bonding Methods

The bonding of fibers gives strength to the web and influences other web properties. There are three major bonding methods that are widely employed to produce webs with sufficient integrity. They are chemical (adhesive based), thermal (using thermoplastic fibers) and mechanical (needling to cause entanglement). Other techniques include spunlacing (using high velocity water jets), ultrasonic bonding (high frequency), stitchbonding and powder bonding.

Chemical bonding. In the chemical/adhesive bonding[6] method, a film forming polymer latex is deposited in and

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around the fibrous structure and then ... ated) to activate bonding. The bonding agent is us... ...yed or saturated in the web. Until recently, the mos... used bonding agents have been synthetic latices ... olyacrylates, polyacetates, polychlorides, polyacrylo... and copolymers. The advantages are the ease of han... and low cost. Latices are effective for hydrophilic fibers, ... useful for synthetic fibers like polypropylene or poly... terepthalate. To be a good binder[8] the polymeric ... should have high strength, good adhesion to fibers, ... flexibility, good elastic recovery, very good resistance to washing, dry cleaning and aging, low weight and color retention.

Thermal Bonding. Thermal bonding[10] of nonwovens involves the use of heat energy to activate an adhesive process for the purpose of interlocking fibers and consequently consolidating or providing dimensi... to fiber webs. The adhesive component is sub... heat. As the adhesive approaches its melting point, ... and the area of contact with more stable ... potential bonding sites. Upon meltin... is attached to a network fiber and flo... of two or more fibers. Once the nonw... the adhesive solidifies and forms a bo... at each fiber contact.

In thermal bonding, fiber surfaces ar... by melting the fiber surfaces or by meltin... the form of a powder, granules or fibers. ... is a method of bonding in which the web is pulled be... heated rollers so that the web is exposed to heat and ... necessary to bond the constituent fibers and layer... rolls[11] may be smooth, embossed or e... smooth rolls lead to the bonding over ... "area bonding") of the web, making ... less drapable. The use of one emboss... tern (at the top) and one smooth ro... only a portion of the web being expos... sure of rolls to be bonded. This is calle... resultant product has good drape, ha...

Polypropylene, polyester, rayon ... fibers used to make webs by therm... monly used fiber is polypropylene ... fiber is used, its high melting temp... ing factor[2]. The thermal bonding ... accepted in the nonwovens industry ... and its many advantages over trad... methods. Low raw material and en... tility, lesser space requirements, ... better product quality characteris... tion rates are the features that h... widely gained acceptance. Since th... are mixed into the web, thermal bon... ly adaptable to the manufacturi... ite structures.

Needlepunching. Needlepunc... ed by mechanically interlocki...

carded web or a spunbonded web ... locking is achieved with thousands ... repeatedly passing into and out of ... transfer. The compression of the web by ... creased interfiber friction.

Today[12] there are many different fiber ... needled fabrics, excluding the high perf... ceramic, glass, steel and carbon. The de... punched fabric can be controlled by fiber ... eb formation and needling density. Surface ch... be controlled by the selection of needle loom ... The diameter of the needles (900 com...) ranges from 0.015 to 0.9 inch. The nee... in length, cross section, barb design ... Some of the important physical prop... needled nonwovens are:

— elongation in the X, Y and Z direc... ing applications)

— ability to attach layers of differ... posites)

— ability to achieve extremely high de...

— high strength (geotextiles)

— superior filtration.

Typical web weight ranges from ... a maximum of 1200 gsm.

Spunlacing. Spunlacing is ... bonding methods. It is a proc... loose fibers on a porous belt or ... terned) screen to form a sheet ... fibers to multiple rows of fine ... The impinging of the water jets on ... glement of fibers. The end product ... appealing pattern depending on ... screen on which it is supported ... passed through a perforated cylinder into a pattern of jets. Web strength ... form transfer of energy from water ... 2200 psi (150 bars) are used to direct ... web.

Hydroentanglement can be ... laid), wet laid or composite ... dependent on the end use prop... product. Cellulosic, polyester ... can be spunlaced. Glass and ... formed webs are spunlaced ... tration, composites and hi... requirements[15]. "Kevlar" ... used by DuPont to produce ... used in specialty applica... and filtration[16].

Fibers having lower bending ... gled[16]. Flat fibers are seen to ... round fibers, although round ... On a relative scale, round fib... trilobal fibers. Thus it is seen ... ier to hydroentangle than polyester ...

to process than aramid fibers. Spunlaced fabrics have good dimensional stability, which also accounts for the drape, softness and strength/weight properties of the fabrics as well as the pilling and abrasion behavior.

Hydroentanglement is considered to be a highly versatile process[18] because it can be used ... with significant differences in ... differences are achieved as a result of ... that are available and also ... sible adjustments of the process ... of the hydroentanglement process ... that this process can be used ... formed webs with melt blowns, ... and scrims in order to get a combination ... that cannot be obtained by the use of a single ... Spunlaced nonwovens have wide acceptance in medical applications, apparel, wipes and in home furnishings.

Ultrasonic bonding. ... thermal bonding methods. ... high frequency vibrations to provide ... respect to small areas to cause ... fibers. Ultrasonic energy is simply ... operating at frequencies greater than ... frequency of 20,000 Hz is used to ... and vibration, which cause ... the area to be bonded. The ... ing to occur at points of ... maximum. Exposure time ... energy is delivered into the ...

The advantages of this ... require binders or needles, energy ... the area of bond and heat ... the fiber to be bonded but ... themselves, thus minimizing ... through excessive heat. The "Pin ... on of the ultrasonic technique ... ing webs of nonwoven fabrics ... in the formation of mattresses ...

Stitchbonding. St... techniques of mechanical ... fibers to give strength ... filament is used to sew ... applications like quilting and ... vens[1].

Worldwide Nonwovens ... wide volume of nonwovens ... North America accounts ... 29% is the share of W... E ... accounts for the remaining ... global nonwoven roll ... $6-10 billion and the ... woven products is ... When the consumption ... on the process used to ... woven type is the staple-fiber based (carded resin and thermal bonded) fabrics accounting for nearly two thirds of the U.S. total of 1.6 billion pounds in 1990, spunbonded processes about one third of total consumption and the remainder by processes such as melt blown, air laid, spunlaced and wet laid[20].

The versatility of raw materials, processes and equipment used to manufacture nonwovens has been one of the principal reasons for the entry of nonwovens into hitherto unfamiliar territories. This versatility has led to products that have properties necessary to be used in a variety of end use markets. ❑

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